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United States Air Force

Environmental Restoration Program

Preliminary Design Analysis Report

Pilot Study - Fire Training Area (OU8)

Loring Air Force Base
Limestone, Maine
Operable Unit 8

December 1994

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PRELIMINARY
DESIGN ANALYSIS REPORT

FIRE TRAINING AREA PILOT STUDY

LORING AIR FORCE BASE
LIMESTONE, MAINE

OPERABLE UNIT 8

CONTRACT NO. F41624-94-D-8054

DELIVERY ORDER NO. 0001

Prepared For:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE

BROOKS AIR FORCE BASE, SAN ANTONIO, TEXAS

Prepared By:

URS CONSULTANTS, INC.

DECEMBER 1994

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LORING AFB

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1.0 INTRODUCTION

This Design Analysis Report (DAR) documents design requirements, design rationale, and design computations and analysis for the free product recovery pilot study to be implemented at the Fire Training Area (FTA) at Loring Air Force Base (Loring or the Base).

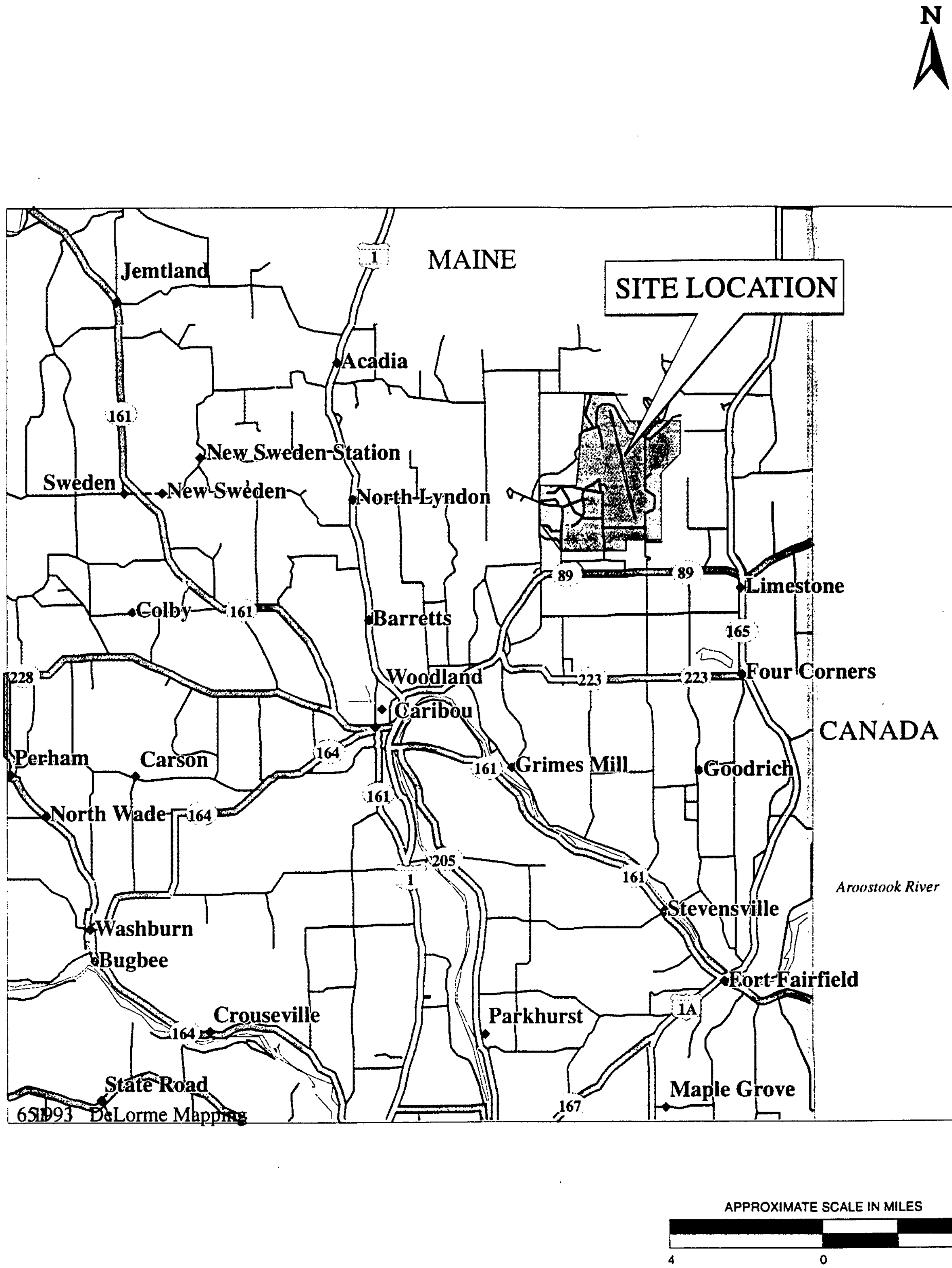
1.1 Site Description

Loring is located in Aroostook County, in the northeast corner of Maine, about 3 miles from the Canadian border (Figure 1-1). The base occupies about 9,000 acres, mostly in the town of Limestone, Maine. Base construction occurred between 1946 and 1953, and improvements were made throughout its operational life. Most recently, the Base was part of the Strategic Air Command. It was officially closed on September 30, 1994 and is now the responsibility of the Air Force Base Conversion Agency (AFBCA).

Remedial Investigation (RI) activities at Loring began in 1983 as part of the Air Force's Installation Restoration Program (IRP). Martin Marietta Energy Systems, Inc. is the RI Program Manager under the Hazardous Waste Remedial Action Program (HAZWRAP). Loring was placed on the National Priorities List in 1990, and, in 1991 a Federal Facilities Agreement, governing all environmental activities at the base, was signed by the USEPA (Region 1), the State of Maine Department of Environmental Protection (MEDEP) and the Air Force. As a result of RI activities, 15 Operable Units (OUs) have been identified at Loring.

1.2 Project Description

The location of the FTA, which is part of OU-8, is shown in Figure 1-2. From 1952 until 1988, simulated aircraft fire training was conducted weekly at the FTA. Reportedly between 148,000 and 284,000 gallons of flammable liquids (jet fuel, solvents, waste oil, etc.) were released into the FTA pit between 1952 and 1981. Based on fire training practices, it is estimated that 50% of the flammable liquids were consumed in the fires, leaving 74,000 to 142,000 gallons to volatilize or percolate into the subsurface soils. In 1981, the pit was upgraded



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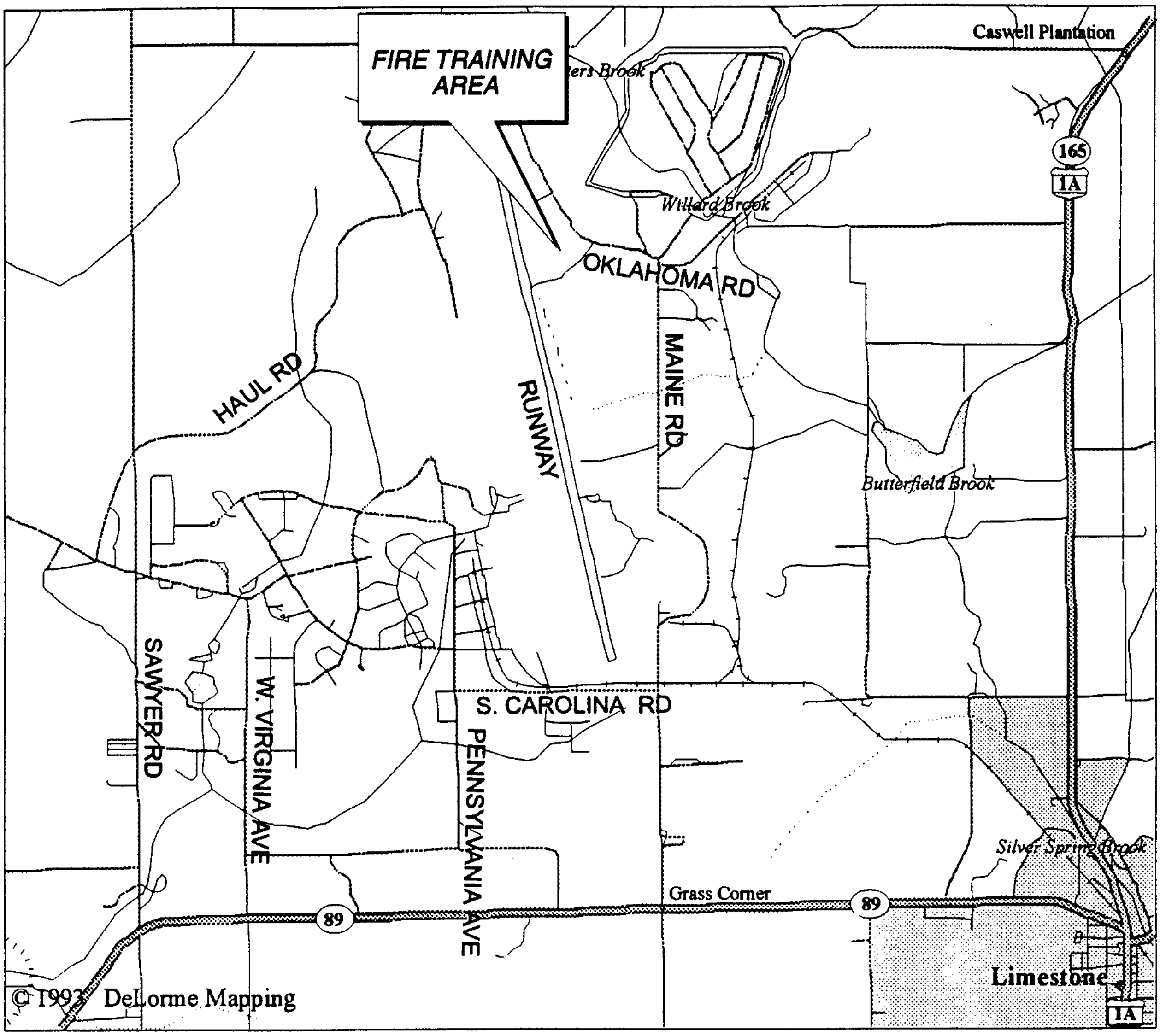
SITE LOCATION MAP

FIGURE 1-1



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FIRE TRAINING AREA LOCATION MAP

FIGURE 1-2

and a bentonite liner, oil/water separator and ancillary underground piping and tanks were added for the collection and storage of unburned fuels. The use of FTA was discontinued in 1988.

Remedial investigation activities have identified free product on the water table surface as well as a dissolved phase contaminant plume (predominantly fuel related compounds) at the FTA. The objective of the proposed pilot study is to investigate the feasibility of recovering the free product and dissolved phase contamination from the shallow bedrock aquifer below the FTA.

The collection system of the proposed pilot study consists of a blast fractured trench in bedrock, recovery wells, injection wells, monitoring wells, a groundwater treatment system and a structure to house the treatment system. The extraction of contaminated groundwater and free product will take place via three wells placed inside a 150 foot long blast fractured trench. Groundwater will be extracted using submersible pumps and product will be collected using skimmers. The extracted groundwater will be processed through a groundwater treatment system consisting of an oil/water separator and an air stripper. Treated water will be re-injected upgradient to drive product and contaminated groundwater towards the recovery trench.

It is anticipated that this proposed pilot study will serve as the remedial action for the FTA. Following the evaluation of the effectiveness of the pilot study system, additional actions may be implemented (i.e., expansion of the trench length and/or installation of additional extraction wells).

2.0 GENERAL

2.1 Authority

On December 23, 1993, the Air Force Center for Environmental Excellence (AFCEE) awarded Indefinite Delivery/Indefinite Quantity Contract No. F41624-94-D-8054 to URS for professional services associated with environmental projects. As part of this contract, on September 29, 1994, URS was awarded Delivery Order 0001 for the Pilot Study at the Fire Training Area, Loring AFB, Maine. A description of all the work activities to be performed under this Delivery Order is presented in the "Draft Work Plan," dated October 1994.

2.2 Applicable Criteria

The design of the recovery system will comply with ASTM, ANSI, National Electric Code, and all other applicable federal, state and municipal codes. Major data sources used in developing the design, including regulations, technical manuals, reference books, and publications, are listed in this section.

2.2.1 General

1. Draft Final Fire Training Area and Underground Transformer Site Operable Unit (OU8) Remedial Investigation Report; August 1994; ABB Environmental Services, Inc.; Portland, Maine; Prepared for HAZWRAP.

2. Draft Remedial Design Work Plan: Landfill Caps, Bioventing, and Soil Removals; October 1994; URS Consultants, Inc.

3. Topographic map based on aerial survey by James W. Sewall Company of Old Town, Maine; provided by ABB Environmental Services, Inc.

4. Manual of Standard Procedures for Planning and Design; March 1990; US Army Corps of Engineers, New York District.

5. Guide Specifications from Construction Criteria Base Subscription; Fourth Quarter 1994; National Institute of Building Sciences.

6. Guide Specifications for Military Construction, HTW Projects, Division 1: General Conditions; September 1993; provided by US Army Corps of Engineers, Kansas City District.

7. Standards Manual for US Army Corps of Engineers, Computer-Aided Design and Drafting (CADD) Systems, EM 1110-1-1807; July 1990; Washington, D.C.

2.2.2 <u>Wells</u>

1. Hydraulics of Groundwater; 1979; Bear, J.; McGraw-Hill; New York.

2. Groundwater and Wells; 1989; Driscoll, F.G.; Johnson Filtration Systems, St. Paul, Minnesota.

3. Engineering Fluid Mechanics; 1987; Bertin, J. I.; Second Edition.

2.2.3 <u>Treatment System and Building</u>

1. Industrial Ventilation: A Manual of Recommended Practice; 16th Edition, 1980. American Conference of Governmental Industrial Hygienists.

2. Cameron Hydraulic Data; 1984; Ingersoll-Rand; Sixteenth Edition.

3. Pneumatic Ejectors: Pumping Contaminated Ground Water, Recovering Hydrocarbons and Extracting Leachate; 1993; Ejector Systems.

4. Minimum Design Loads for Building and Other Structures; American National Standard - A58.1, 1982; American National Standards Institute, Inc.

5. Manual of Steel Construction. Allowable Stress Design; 9th Edition, 1991; American Institute of Steel Construction, Inc.

6. Standard Handbook for Civil Engineers; Third Edition, 1983. Merrit, F.S.; McGraw-Hill Book Company.

7. Building Code Requirements for Reinforced Concrete; ACI 318-83; Appendix B Alternate Design Method; Revised 1986; American Concrete Institute.

8. Building Construction Costs Data; 1994; R.S. Means Company.

3.0 FIELD INVESTIGATIONS

Investigations of OU-8 began in the early 1980s with a records search by CH2M Hill, followed by a site inspection by Roy F. Weston, Inc. In 1988, ABB Environmental Services, (ABB-ES, formerly E.C. Jordan) commenced RI activities at the FTA. The purpose of the RI was to characterize the site's geologic and hydrogeologic conditions, as well as to evaluate the nature and distribution of the contaminants present. The results of the RI, which directly relate to the design and construction of the free product recovery system, are discussed in the following sections.

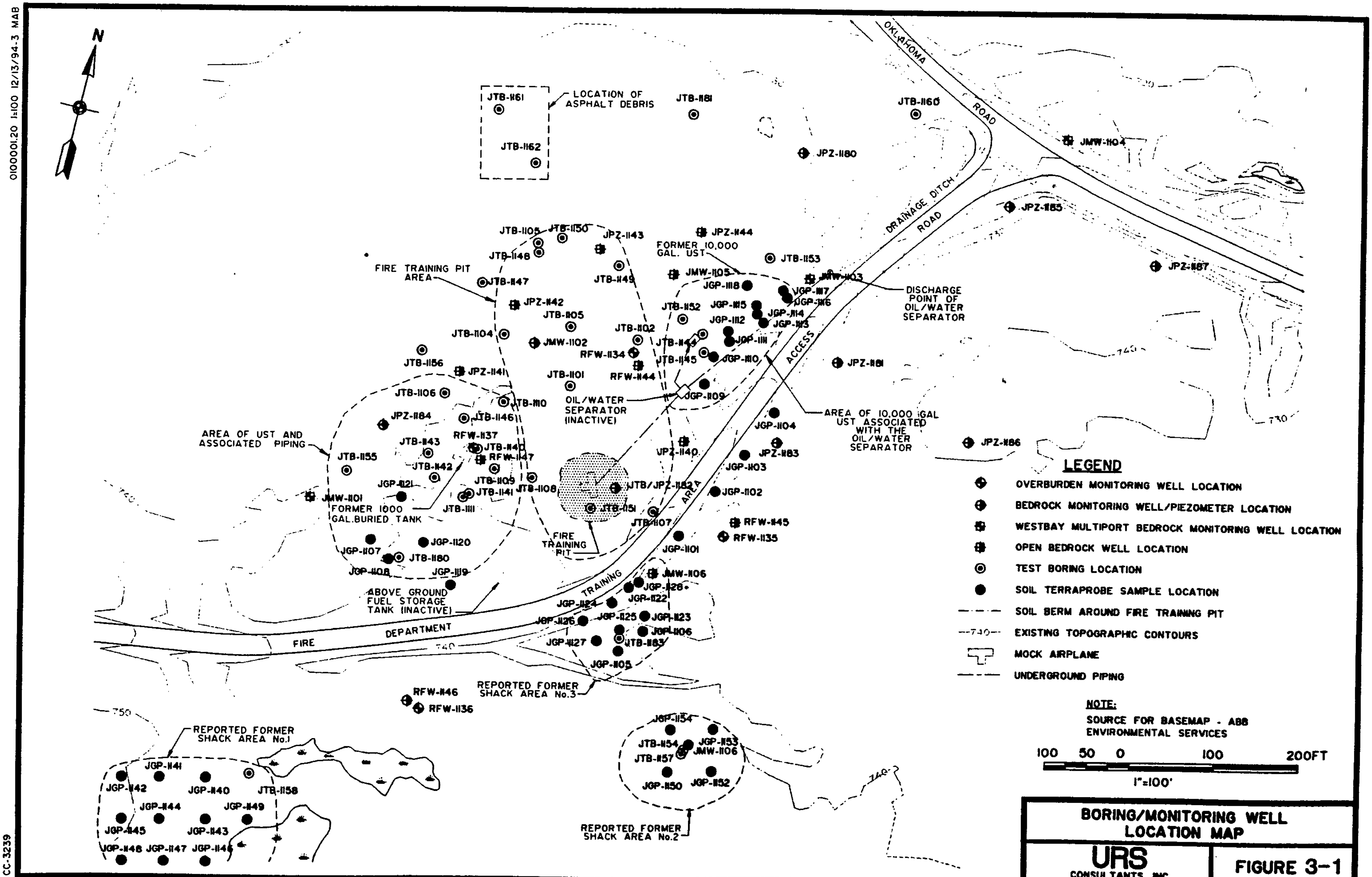
3.1 Geology

The geology at the FTA was characterized by the interpretation of borehole geophysical logs, rock core and soil boring logs, as well as visual observations. The locations of the borings and monitoring wells installed during the RI are shown in Figure 3-1. Boring logs and well construction diagrams are included in Appendices I and L of the RI report.

The geology consists of moderately thin, glacially derived soil overlying bedrock. Overburden soil consists of approximately 10 feet of fill (excavated and backfilled basal till) around the FTA pit and dense basal till consisting of brown to olive silty sand and sandy silt in other parts of the site. Bedrock is gray to bluish gray, layered, pelitic limestone ranging in depth from approximately 10 to 20 feet below ground surface (bgs) from southwest to northeast across the site, respectively.

Foliation and bedding observed in the rock cores indicated that the bedrock is steeply dipping, ranging from 45 degrees to vertical. The wide variation in bedding angle observed in one boring may indicate that the formation underwent metamorphism and folding.

Fracture zones were encountered throughout three boreholes which were cored (JMW-1102, JMW-1103, and JMW-1104). The depth of near surface fractures varied between boreholes. Borehole JMW-1102 revealed a highly weathered zone of bedrock 12 to 17 feet bgs. Below the highly weathered zone in JMW-1102, rock quality designations (RQD) generally



BORING/MONITORING WELL LOCATION MAP

URS CONSULTANTS, INC.

FIGURE 3-1

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ranged from 70 to 90 percent. In contrast, bedrock was encountered at a depth of 15 feet at JMW-1103; however, competent rock was not encountered until 36 feet bgs. The first core run from 36 to 37.4 feet bgs revealed a RQD of 29%. The borehole was advanced from 37.4 to 59.0 feet bgs using a roller cone when coring was continued. Subsequent coring (59 to 92.3 feet bgs) revealed RQDs ranging from 50 to 100%. Coring of JMW-1104 revealed results similar to those of JMW-1102 in that approximately 5 feet of weathered rock was encountered. The RQDs from JMW-1104 generally increased with depth, but no trend was apparent in JMW-1102 or JMW-1103. The fractures in the rock occurred throughout the boreholes to approximately 170 feet bgs (the maximum depth investigated).

Acoustic televiewer (ATV) logs were used to evaluate the attitude (strike and dip) of the fractures and/or bedding planes in three open-hole bedrock wells (RFW-1144,-45,and-47). The ATV borehole geophysical survey identified several commonly occurring fracture orientations. The azimuthal range of strike of the most common fractures was northeast-southwest to northwest-southeast, with dip to the northwest and northeast, respectively. The dips of these fractures was generally steep, 45 degrees to vertical.

The conventional log suite (e.g. caliper, fluid resistivity, normal resistivity, single point resistance and temperature logs) was used to identify hydraulically conductive zones. The lithology of the formation did not significantly vary from boring to boring, or with depth within a specific boring. Cross-hole correlation based on depth/orientation of apparent fractures was inconclusive due to the variability in the occurrence and attitude of the fractures.

3.2 Hydrogeology

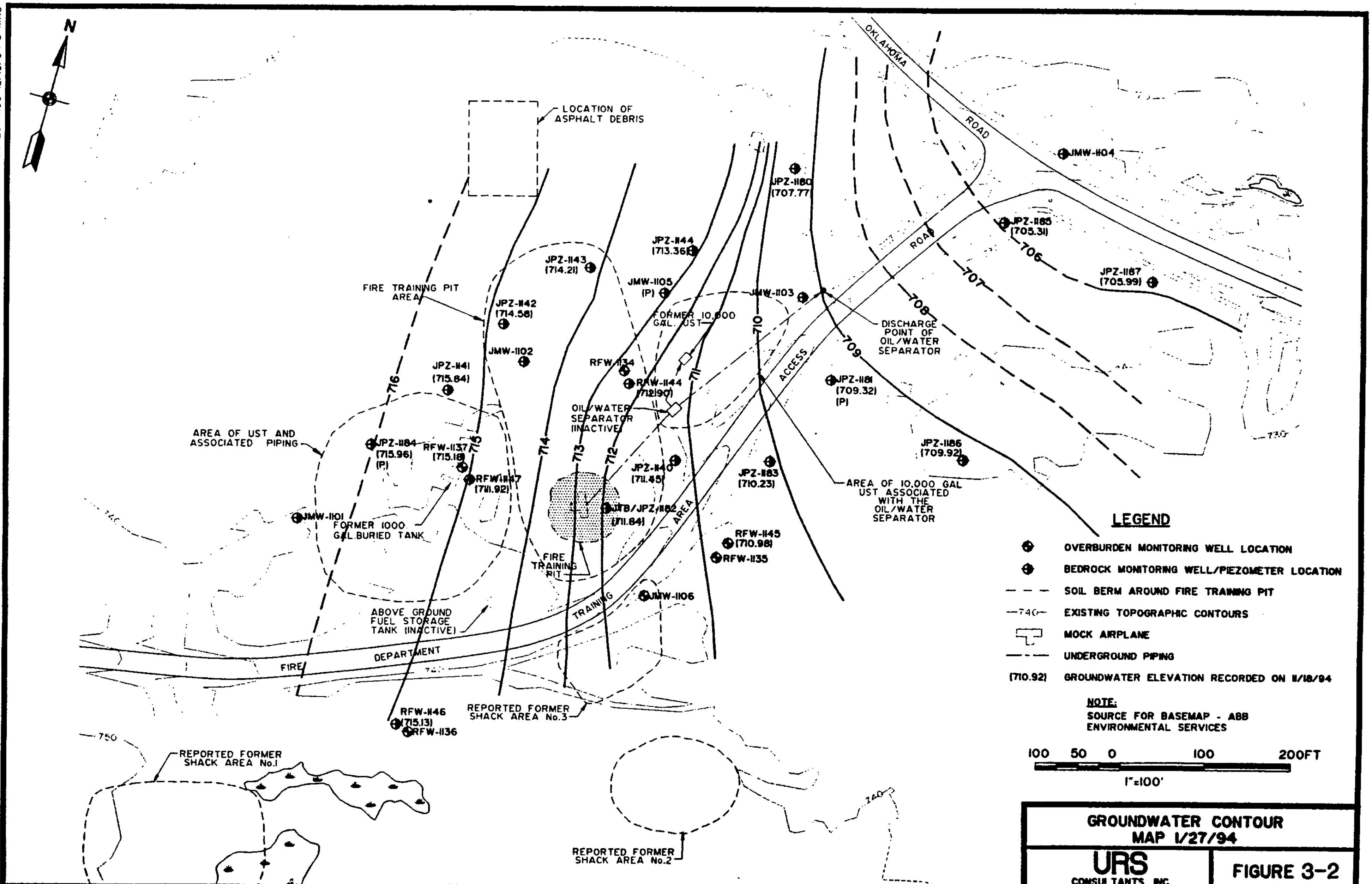
During the investigation period, groundwater at the FTA generally occurred only in the bedrock at an average depth of 20 feet bgs. During the months of high precipitation, the lower few feet of till was observed to be saturated in the northeast portion of the site (between JMW-1103 and JMW-1104). The groundwater within the bedrock is transmitted primarily through secondary porosity features such as fractures and along bedding planes. The groundwater flow system in the fractured bedrock is complex; the frequency, orientation, and connectedness of joints and cleavage planes, and the presence of larger scale features such as fractures, exerts a strong influence on the rate and direction of groundwater movement.

In 1988 and 1989, short-term and long-term pumping tests were conducted to assess the hydrogeologic properties of the bedrock aquifer and to evaluate product accumulation rates under drawdown conditions. Results of the pump test indicated that aquifer pumping rates of approximately 22 gpm were attainable. The aquifer's transmissivity ranged from 77 to 530 ft^2/day and storativity values ranged from 0.01 to 0.00435. Drawdown observed in the test array of monitoring wells was slightly asymmetrical, with the long axis orientated east to west, which is indicative of a zone of high transmissivity in this direction. This east west orientation was interpreted to represent a major orientation of fractures.

Water level measurements have been taken from the FTA wells by ABB-ES since 1988 to evaluate horizontal and vertical gradients. ABB-ES' water level data are summarized in Appendix A of the RI report. To evaluate groundwater flow directions, water table contour maps were developed by URS using ABB-ES' data from January 27, 1994 and a round of measurements taken by URS on November 18, 1994 (see Figures 3-2 and 3-3). The interpreted groundwater contour maps revealed a similar pattern of groundwater flow to the east-northeast across the site. The hydraulic gradient across the site varies from 0.010 feet/feet in easterly direction (from JPZ-1184 to JPZ-1182), to 0.013 feet/feet in a northeasterly direction (from JPZ-1183 to JPZ-1185). It should be noted that during different times of the year the flow regime could be quite different due to increases or decreases in infiltration rates.

3.3 <u>Delineation of Free Product Layer</u>

Since 1985, free product thickness measurements have been recorded by previous investigators. Figure 3-4 illustrates the estimated distribution of product measured by URS on November 18, 1994. It appears that two separate free product plumes are present at the FTA, one in the vicinity of the former 1,000 gallons UST, and the other east-northeast of the fire training pit. The eastern area of free product delineated by URS (Figure 3-4) is generally consistent with the area delineated by ABB-ES using September 1993 data (RI Figure N-4). Notable exceptions included: URS detected product in three wells in this area of the FTA (JMW-



GROUNDWATER CONTOUR MAP 1/27/94

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FIGURE 3-2

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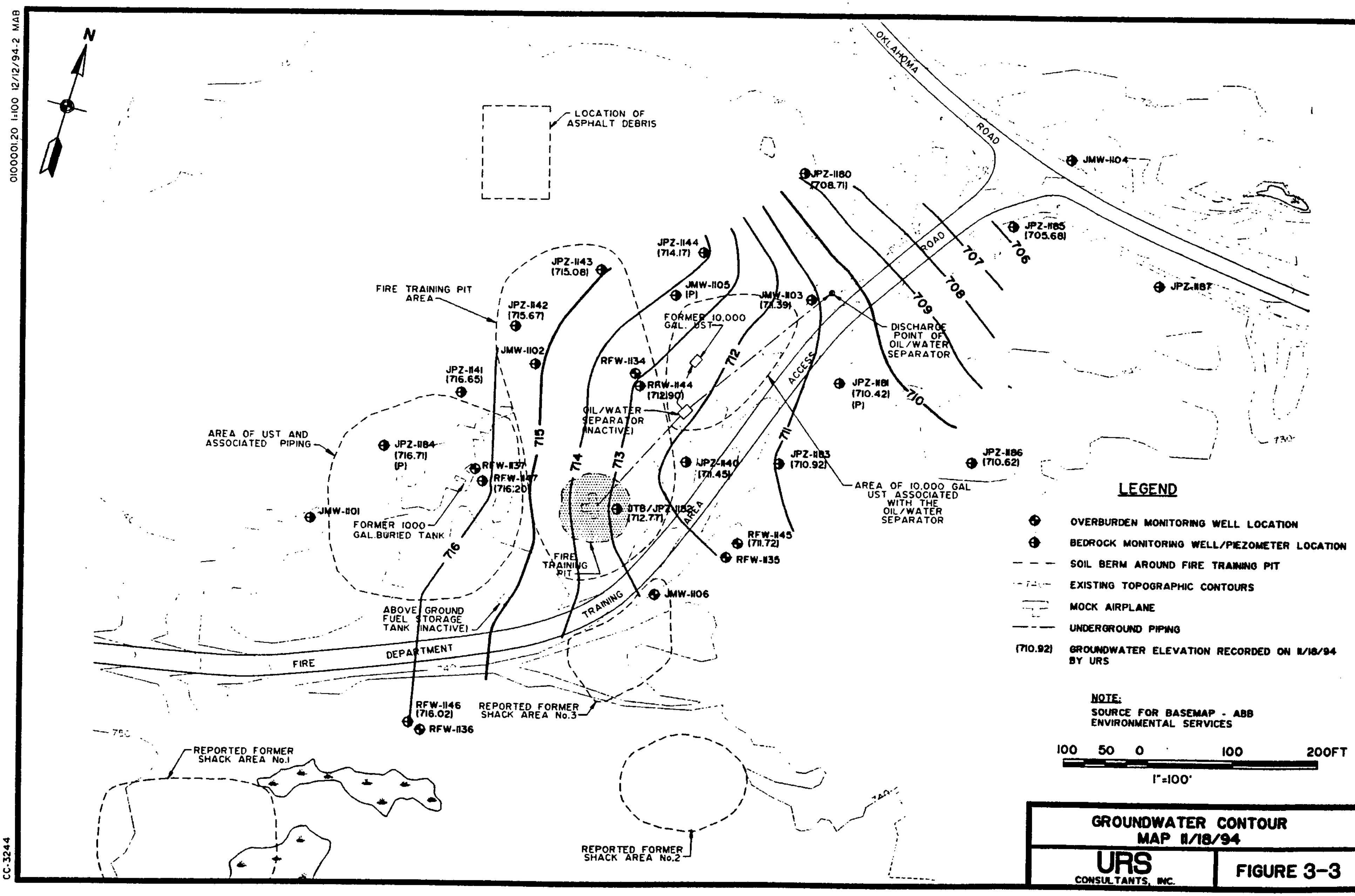

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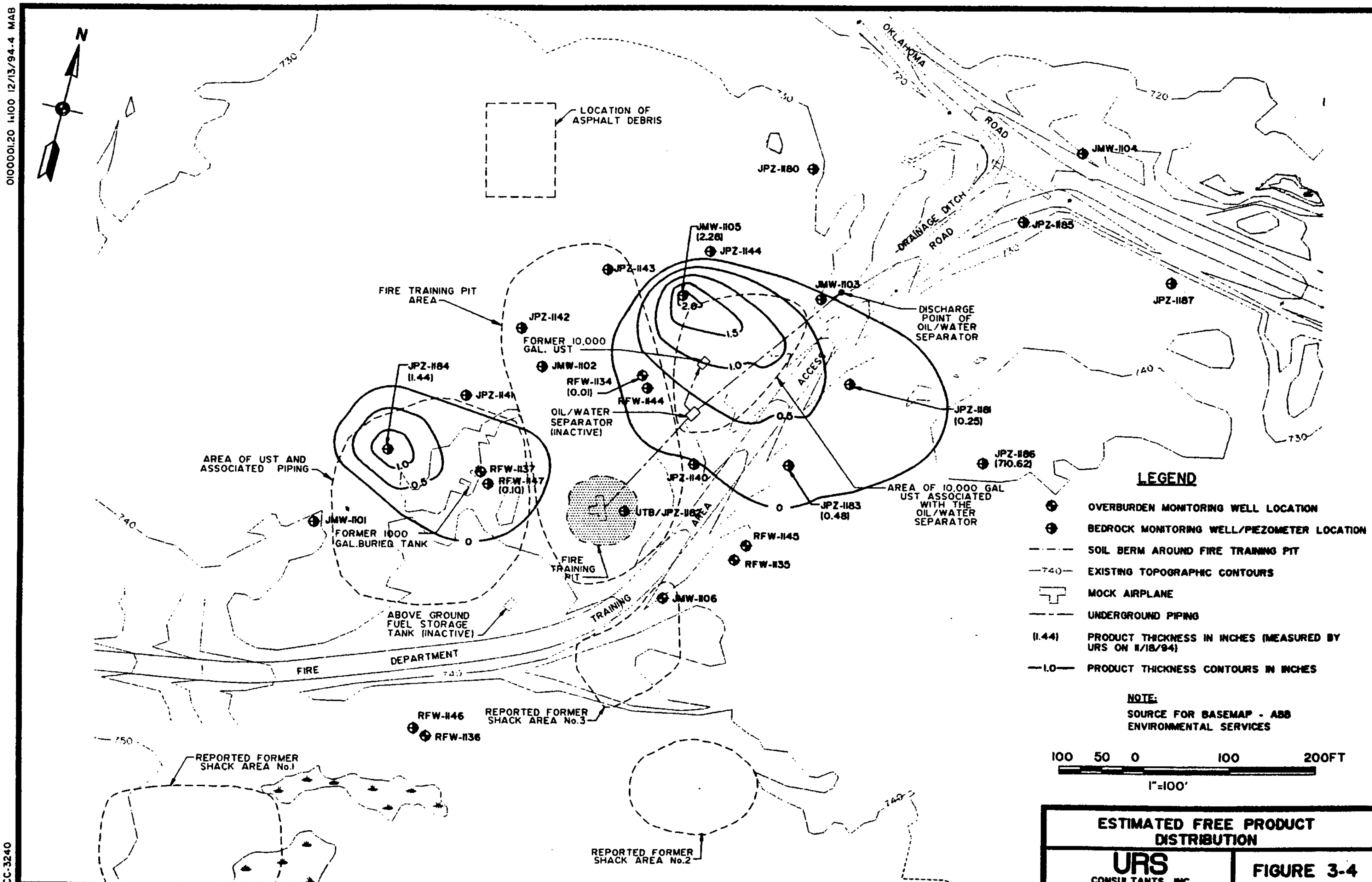


ESTIMATED FREE PRODUCT DISTRIBUTION

FIGURE 3-4

1105, JPZ-1181 and JPZ-1183) while ABB-ES detected product in two wells (JMW-1105 and JPZ-1181), and URS detected significantly less product in well JPZ-1181 (0.25 inches versus 10.8 inches). The western free product plume was not detected by ABB-ES during the September 1993 monitoring round; however, earlier monitoring rounds (May 1988 and September 1991) did reveal a free product plume in the vicinity of well RFW-1147.

Most recent product thickness measurements indicate that the bulk of the free product is migrating eastward in the predominant direction of groundwater flow, along fracture planes. Based on the interpreted eastward direction of groundwater flow, as well as pumping test results which indicated that a highly transmissive zone is orientated east-west, the product recovery trench will be located east of the leading edge of the eastern free product plume.

3.4 Dissolved Phase Contaminant Plume

Table 3-1, taken from the RI, is a summary of the maximum, minimum and mean concentrations of organic compounds detected in groundwater at the FTA. These were used in design calculations for the groundwater treatment system.

Thirteen wells and piezometers have been sampled for off-site laboratory analysis. Eight of the thirteen wells and piezometers were also field screened for targeted Volatile Organic Compounds (VOCs), Semivolatile Organic Compounds (SVOCs), and Fuel Hydrocarbons (FHCs).

Field screening in 1990 detected benzene, toluene, ethylbenzene, xylene (BTEX), naphthalene, and FHCs. Field screening in 1993 detected BTEX, naphthalene, FHCs, cis-1,2-dichloroethene, and 1,2-dichloroethane.

Off-site laboratory analysis confirmed field screening results. BTEX and polynuclear aromatic hydrocarbons (PAHs) are pervasive in groundwater at the FTA and have been detected at concentrations above the National Drinking Water Regulations Maximum Contaminant Levels (MCLs) and Maine Established Maximum Exposure Guidelines (MEGs) for compounds which MCLs have not been established. The vertical and horizontal extent of VOC and SVOC

TABLE 3-1
SUMMARY OF ORGANIC COMPOUNDS DETECTED IN GROUNDWATER
FIRE TRAINING AREA

LORING AIR FORCE BASE

Compound	Range Of SQLs	Frequency Of Detection	Minimum Detected Concentration	Maximum Detected Concentration	Mean Of All Samples	Background	MCL	MCLG	CPC?	Notes
Fire Training Area Groundwater - 1993 (mg/L)										
Chloromethane	0.001 - 0.1	1 / 17	0.0007	0.0007	0.012			0.003	N	
Vinyl Chloride	0.0001 - 0.0001	3 / 17	0.0001	0.0007	0.011		0.002	0.0001	Y	MEG
1,1-Dichloroethane	0.001 - 0.1	1 / 17	0.0005	0.0005	0.012			0.005	N	
Chloroform	0.001 - 0.1	1 / 17	0.004	0.004	0.012		0.1		N	
2-Butanone	0.004 - 0.5	2 / 17	0.004	0.008	0.057			0.17	N	
1,1,1-Trichloroethane	0.001 - 0.1	1 / 17	0.0002	0.0002	0.011		0.2	0.2	N	
Carbon Tetrachloride	0.001 - 0.1	2 / 17	0.004	0.024	0.013		0.005	0.0027	Y	MEG
Trichloroethene	0.001 - 0.1	2 / 17	0.0008	0.005	0.012		0.005	0.005	N	
Benzene	0.001 - 0.1	11 / 17	0.0004	0.089	0.016		0.005	0.005	Y	
4-Methyl-2-Pentanone	0.004 - 0.5	1 / 17	0.32	0.32	0.061				N	No Standard
Toluene	0.001 - 0.1	7 / 17	0.0002	0.19	0.020		1	1.4	N	
Chlorobenzene	0.001 - 0.1	1 / 17	0.0003	0.0003	0.011		0.1	0.047	N	
Ethylbenzene	0.001 - 0.001	12 / 17	0.001	0.2	0.059		0.7	0.7	N	
Styrene	0.001 - 0.1	2 / 17	0.0002	0.011	0.012		0.1	0.005	Y	MEG
Total Xylenes	0.001 - 0.001	12 / 17	0.0004	0.85	0.223		10	0.6	Y	MEG
Phenol	0.01 - 0.1	1 / 17	0.04	0.04	0.012				N	No Standard
4-Methylphenol	0.01 - 0.1	3 / 17	0.002	0.16	0.019				N	No Standard
2,4-Dimethylphenol	0.01 - 0.1	3 / 17	0.004	0.009	0.013				N	No Standard
Naphthalene	0.01 - 0.01	10 / 17	0.014	0.12	0.030			0.025	Y	MEG
2-Methylnaphthalene	0.01 - 0.01	11 / 17	0.001	0.2	0.046				N	
Fluorene	0.01 - 0.1	1 / 17	0.001	0.001	0.013				N	
Phenanthrene	0.01 - 0.1	2 / 17	0.001	0.013	0.013				N	
Pyrene	0.01 - 0.1	1 / 17	0.002	0.002	0.013				N	
bis(2-Ethylhexyl)phthalate	0.01 - 0.24	1 / 17	1.2	1.2	0.090		0.006	0.025	Y	MCL and MEG
alpha-BHC	0.000005 - 0.000024	3 / 16	0.0000036	0.0000082	0.0000062				N	No Standard
beta-BHC	0.000005 - 0.000024	1 / 15	0.000044	0.000044	0.0000078				N	No Standard
gamma-BHC (Lindane)	0.000005 - 0.000024	2 / 15	0.0000032	0.000046	0.000008		0.0002	0.0002	N	
Aldrin	0.000005 - 0.000024	1 / 15	0.0000033	0.0000033	0.0000057				N	No Standard
Endosulfan II	0.00001 - 0.00005	1 / 15	0.000043	0.000043	0.0000129				N	No Standard
4,4'-DDD	0.00001 - 0.00005	1 / 16	0.00059	0.00059	0.0000478				N	No Standard
4,4'-DDE	0.00001 - 0.00005	1 / 16	0.000023	0.000023	0.000012				N	No Standard

MCL - Maximum Contaminant Level (National Drinking Water Regulations)
MCLG - Maximum Contaminant Level Goal
CPC - Chemical of Potential Concern
MEG - Maximum Exposure Guideline (Maine Department of Environmental Protection)

J:\0100007.10\QPRO\STRIPDES.WB1\jn 12/13/94 contamination has not been delineated. Inorganics, including arsenic and barium, have also been detected frequently in groundwater samples. Chlorinated VOCs have been detected in several wells at concentrations above MCLs/MEGs. Aroclor-1260 was detected in a sample from one monitoring well. Analytes have been detected in an apparent upgradient well; the flightline may be a source of upgradient contamination.

Groundwater samples at the FTA contained tentatively identified compounds (TICs) coincident with the target compounds detected. The VOC TICs ranged from none detected to 4.9 mg/L. The SVOC TICs ranged from none detected to 14.9 mg/L. The TICs detected in the groundwater were primarily alkylbenzenes, cycloalkanes, alkanes up to C-10, and naphthalenes. These compounds are characteristic of gasoline, kerosene, diesel, and jet fuels.

4.0 DESIGN SCOPE

The product collection system will consist of a blast fractured trench in bedrock, recovery wells, injection wells, monitoring wells, a groundwater treatment system and a structure to house systems. The extraction of contaminated groundwater and free product will take place via three wells placed inside a 150 foot long blast fractured trench. Groundwater will be extracted using submersible pumps and product will be collected using skimmers. The treated water will be re-injected upgradient using groundwater injection wells. This section discusses the analysis and design of the collection system.

4.1 Design Rationale

The proposed pilot study will address the free product in the larger of the two free product plumes located northeast of the FTA pit (see Figure 4-1).

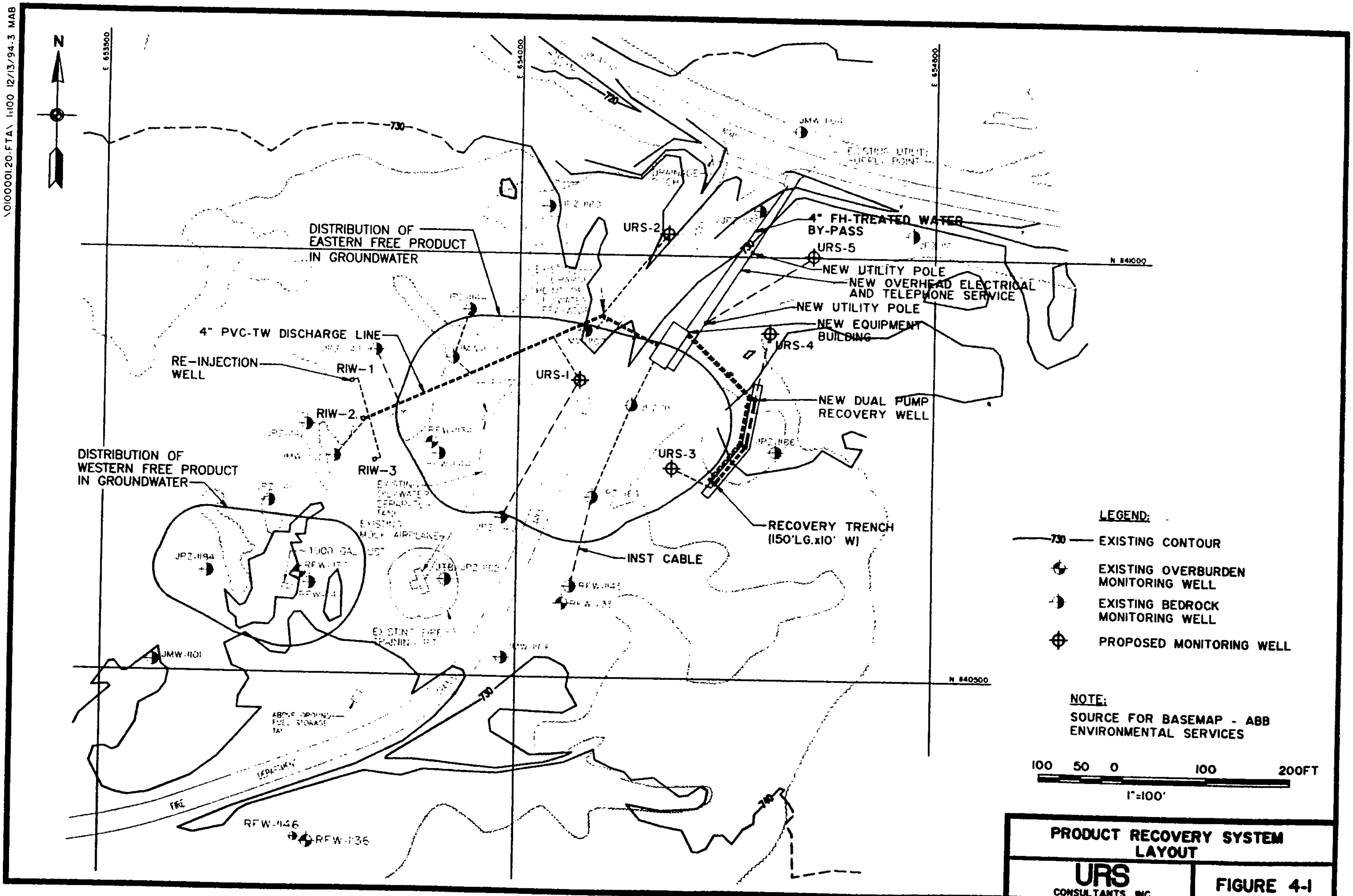
For the collection system to function effectively, it must meet the following criteria:

- The blast fractured bedrock trench must create a zone which will intercept the majority of the groundwater/product bearing fractures.

- The pumping rate of the recovery wells within the trench must be sufficient to create a groundwater capture zone to encompass the floating product plume.

- The depth of the trench/recovery wells must be sufficient to allow for sufficient drawdown of the water table for free product recovery and to collect dissolved phase contaminated groundwater detected from deeper within the aquifer.

- A method of monitoring the extent of the capture zone will be required (i.e. monitoring well system).



PRODUCT RECOVERY SYSTEM LAYOUT

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FIGURE 4-1

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- The treatment system must have the capability of separating groundwater and product, and also be able to remove dissolved contaminants so the effluent meets all state and federal requirements.

- The system must have sufficient capacity (reliability) to collect, pump and transport unanticipated increases or decreases in groundwater/product volumes resulting from inaccuracies in flow rate estimates caused by such factors as hydraulic conductivity variations.

4.2 Groundwater Extraction Analysis

A groundwater extraction analysis was performed in order to design a product recovery system with a capture zone encompassing the eastern free product plume delineated by URS (Figure 4-1). Details of this analysis, including the underlying assumptions and calculations, are presented in Appendix A. The results of the analysis are summarized as follows:

- Based on the interpreted direction of groundwater flow, as well as pumping tests which indicated a highly transmissive zone is orientated east-west, the product recovery trench should be located east of the leading edge of the free product plume as shown on Figure 4-1.

- In order to intercept groundwater/product from all fractures the required trench length would have to be approximately 360 feet by approximately 5 feet wide. (The pilot study trench will only be 150 feet long.)

- Based on the need for a sufficient drawdown allowance within the recovery wells, the trench should be installed to a depth of at least 70 feet bgs. This would allow for a water column within the extraction wells of approximately 50 feet.

- The proposed depth of the trench and wells should also allow for the recovery of dissolved phase contamination which was revealed to occur at depths greater than 100 feet bgs.

- Three groundwater extraction wells placed within the recovery trench should be adequate to produce a capture zone encompassing the free product plume.

- Pumping test and slug test data were used to estimate groundwater extraction rates. Using the highest hydraulic conductivity value of 30 ft/day the anticipated maximum combined extraction rate for the three wells is 105 gpm.

- The lowest combined extraction rate (assuming the lowest conductivity value of 1.41 feet/day) is approximately 7 gpm.

- The extraction rate analysis was such that the maximum depression in the water table will not exceed 10 feet to prevent the downward migration of floating product. The water table may have to be depressed in excess of 10 feet to create a capture zone which encompasses the free product plume.

- The treated groundwater will be re-injected into the bedrock aquifer upgradient of the plume. Calculations indicate that a minimum of two injection wells will be required.

- The western free product plume is much smaller than the eastern plume. Although the western plume will not be addressed by this pilot study, the extraction analysis results indicate that a similar trench/recovery well system could be used. Extraction rates for the western product plume were estimated to be 30% lower than that of the eastern plume.

- It is anticipated that the western product plume would require 2 extraction wells placed in a downgradient trench of 150 feet in length. Two upgradient injection wells should be able to return the water to the aquifer.

- The groundwater treatment system should be capable of processing the maximum amount of groundwater which could be extracted from the eastern and western trenches. The estimated combined maximum withdrawal rate for the two areas is 140 gpm.

4.3 Design

The following sections describe the designed components of the product recovery system.

4.3.1 Recovery Wells/Recovery Trench

The product recovery trench will be 150 feet in length x 10 feet wide x 70 feet deep. The trench will be performed utilizing controlled blasting. Although the groundwater extraction analysis indicated that the required trench length is 360 feet, since this is a pilot study to investigate the feasibility of this method the proposed trench length has been reduced to 150 feet. Following operation and evaluation of the system, the trench length may be increased and additional recovery wells added. The controlled blasting will be accomplished by advancing as many shot holes required to create a rubble zone the entire length, width and depth of the trench. The design will require that 90 percent of the rubble will be no larger than 3 inches in diameter. Upon completion of the blasting the rubble will be left in place and three product recovery wells will be installed through the rubble to a depth of 70 feet bgs. Proposed well locations are shown in Figure 4-1. The recovery wells will be installed through 8 inch steel casing to enable placement of the sand pack and grout. The recovery wells will be constructed of type 304 stainless steel riser and screens. The screens will be of wire wound construction with 0.03 slot openings. The screens will be installed from approximately 15 feet to 70 feet bgs. The sand pack will consist of a Morie number 3 well sand or equal. Surface manways will be installed at each well to house piping and pump equipment. Survey of each recovery well and the limits of the trench will be performed to obtain exact locations and elevations utilizing existing control.

4.3.2 Injection Wells

Three groundwater injection wells will be installed upgradient of the eastern free product plume (Figure 4-1) to re-inject treated groundwater into the aquifer. By re-injecting groundwater upgradient of the plume, free product should be driven toward the recovery trench. Each injection well will be constructed by installing 6-inch diameter steel casing into competent bedrock and boring a 4 inch diameter hole to approximately 70 feet bgs. The 6-inch steel casing will be grouted into the competent bedrock and the well will be completed as an open rock hole well. No fracturing is anticipated to be necessary. Surface manways will be installed at each well to house piping and monitoring equipment. Survey of the injection wells will be performed to obtain exact locations and elevations utilizing existing control.

4.3.3 Monitoring Wells

Five new monitoring wells will be installed to locate the leading edge of the floating product plume before constructing the trench and to provide data needed to evaluate the effectiveness of the system during operation. In addition, nine existing monitoring wells also will be used to monitor the system during operation. The new monitoring wells will be 4-inch diameter open hole wells installed to approximately 70 feet bgs. The observation wells will be cased through the overburden and weathered bedrock using 6 inch diameter steel casing. Each well will have a locking, weather tight protective cap. Proposed monitoring well locations are shown in Figure 4-1. The monitoring wells will be field surveyed to obtain coordinates and elevations.

4.3.4 Groundwater Treatment System

4.3.4.1 Treatment Objectives

It is presumed that the treated groundwater will be re-injected into the bedrock subsurface or discharged into a surface drainage ditch. The treatment system effluent will meet all state and federal requirements.

4.3.4.2 Description of Treatment Process System

The treatment process train is shown on the Piping and Instrumentation Drawings. The design includes the following major elements:

- Groundwater recovery pumps (P-1A, P-2A, P-3A)
- Product recovery pumps (P-1B, P-2B, P-3B)
- Product holding tank (T-210)
- Oil/water separator (T-201)
- Shallow tray air stripper (S-301)
- Programmable logic controller (PLC)
- Equipment building

4.3.4.3 Design Criteria

The process design is based on the design rationale presented in subsection 4.1 and groundwater extraction analysis presented in subsection 4.2 of this report. The technical rationale for design of the treatment facility is presented in the following subsections.

Groundwater/Product Recovery. The treatment system will utilize a dual pump system for groundwater and product recovery. The dual pump system will consist of 3 electric skimmer pumps and 3 electric groundwater depression pumps.

The skimmer pumps shall be located at the groundwater surface. The pumps will remove free product from the groundwater surface and pump the product through double wall polyvinyl chloride (PVC) pipe directly into a product holding tank (T-210). The skimmer pumps are of stainless steel construction and utilize oleophilic/hydrophobic screens to recover water-free product. The pumps are estimated to collect less than 10 gallons of free product per day per pump.

The groundwater collection pumps will create a cone of depression around the recovery trench to capture the contaminated groundwater plume. Based on the groundwater extraction analysis a pumping rate of 35 gpm per pump is anticipated. To allow for unanticipated conditions in the analysis, each groundwater pump will be designed to process up to 50 gpm. The pumps will be controlled through the use of motor operated valves thus, allowing the flow rate to be adjusted from approximately 25 to 50 gpm to meet actual conditions. The groundwater extracted pumps will be of stainless steel construction and will pump directly into an oil/water separator (T-201).

Oil/water Separator. The oil/water separator will remove suspended solids and oil droplets greater than 20 microns in size from the groundwater. Oil collected within the separator will be gravity discharged into the product holding tank (T-210). Suspended solids removed from the groundwater will be hand pumped to a 55-gallon drum for off-site disposal. The oil/water separator will be of reinforced polyester resin construction and shall utilize vertically positioned oleophilic tubes for the removal of oil. Effluent from the separator will be transferred to an air stripper (S-301) through a transfer pump (P-201).

Shallow Tray Air Stripper. The shallow tray air stripper will remove volatile organic contaminants from the groundwater by blowing air through the groundwater. The contaminated groundwater enters baffled stainless steel aeration trays in the air stripper increasing the surface area of the groundwater to be treated. Air blown up through the aeration trays generates a large mass transfer surface area where the contaminants are volatilized. The treated effluent from the air stripper then is discharged to the re-injection wells.

Product Holding Tank. The product holding tank has been sized to allow a minimum of 14 days of system operation before the tank needs to be emptied. The tank size is based on the 3 skimmer pumps operating at 10 gpd each for a total of 30 gpd. Additional storage capacity is provided to account for gravity discharge from the oil/water separator. The product holding tank will be of steel construction.

Programmable Logic Controller. The programmable logic controller (PLC) will be capable of monitoring, trending, and controlling of the treatment system from a remote computer. The system shall allow historical data to be down loaded to a computer for storage and presentation daily by automatic means through the use of an automatic dialing telephone modem. The PLC, through the telecommunications link, will be able to report alarm conditions and perform diagnostic services on the treatment system.

Equipment Building. The equipment building will be a 50 foot long by 20 foot wide steel framed building. The equipment building will house the proposed treatment equipment and allow room for additional treatment systems and equipment to be installed as required to meet additional treatment requirements. Calculations for the equipment to be used in the treatment process and for the equipment building are presented in Appendix C.

5.0 PERMITS

It is anticipated that discharges from the free product recovery pilot study potentially will require state permits or approvals. Discharges from the pilot study will include treated water and volatile organic compound (VOC) emissions from the air stripper. The treated water will be re-injected to the fractured bedrock. The VOCs will be released to the atmosphere without treatment.

In order to capture the free phase product at the FTA, groundwater must be pumped from the aquifer, treated and discharged. The groundwater discharge will be re-injected to the fractured bedrock aquifer utilizing re-injection wells. The re-injection wells are assumed to be classified as Class V wells (MEDEP Regulations, Chapter 543). Discharge of fluids into or through a Class V well is allowable so long as there are no violations of any Maine Primary Drinking Water Standards. The air stripper has been designed and sized so that the treated water does not violate any Maine Primary Drinking Water Standards.

VOC emissions from the air stripper as designed will be .0356 pounds per hour. The system does not include any VOC emission control systems. Based on comments from the Maine Department of Environmental Protection, Bureau of Air Quality, requirements for VOC emission control will be considered in the final design. Air stripper design calculations are provided in Appendix B.

The MEDEP Regulations for air emissions (Chapter 110) and groundwater discharge through injection (Chapter 543) are included for reference in Appendix B.

6.0 SPECIFICATIONS

The specifications were generally developed according to the requirements of the U.S. Army Corps of Engineers (USACE) New York District's "Manual of Standard Procedures for Planning and Design" dated March 1990. The Division 1, General Conditions were developed primarily from guide specifications provided on disk by the Kansas City District. Other divisions used the Guide Specifications for Military Construction found in the "Construction Criteria Base (CCB)", published by the National Institute of Building Sciences. The technical specifications for Construction Specifications Institute (CSI) Divisions 1 through 15 are complete have been provided separately. CSI Division 16, Electrical, will be provided with the next submission. The Air Force Center for Environmental Excellence (AFCEE) will provide the design drawings and technical specifications to one of its remedial action contractors to implement as a Delivery Order to their contract.

7.0 CONSTRUCTION SCHEDULE

The general anticipated sequence of major construction activities for the pilot study is presented on Figure 7-1. Generally, the construction contractor will ultimately be responsible for overall effective construction scheduling and coordination.

The task descriptions presented in Table 7-1 are generally self explanatory. Tasks 11, 12 and 13, Phase I, II and III startup consist of the actual testing and operation of the system. Phase I consists of initial startup of the system using potable water to demonstrate the equipment has been properly installed. Phase II consists of initial operation of the system using groundwater to demonstrate that various components of the system operate properly and concurrently. Phase III is a longer duration operation test of the system's performance. A detailed description of these tasks are presented in the technical specifications.

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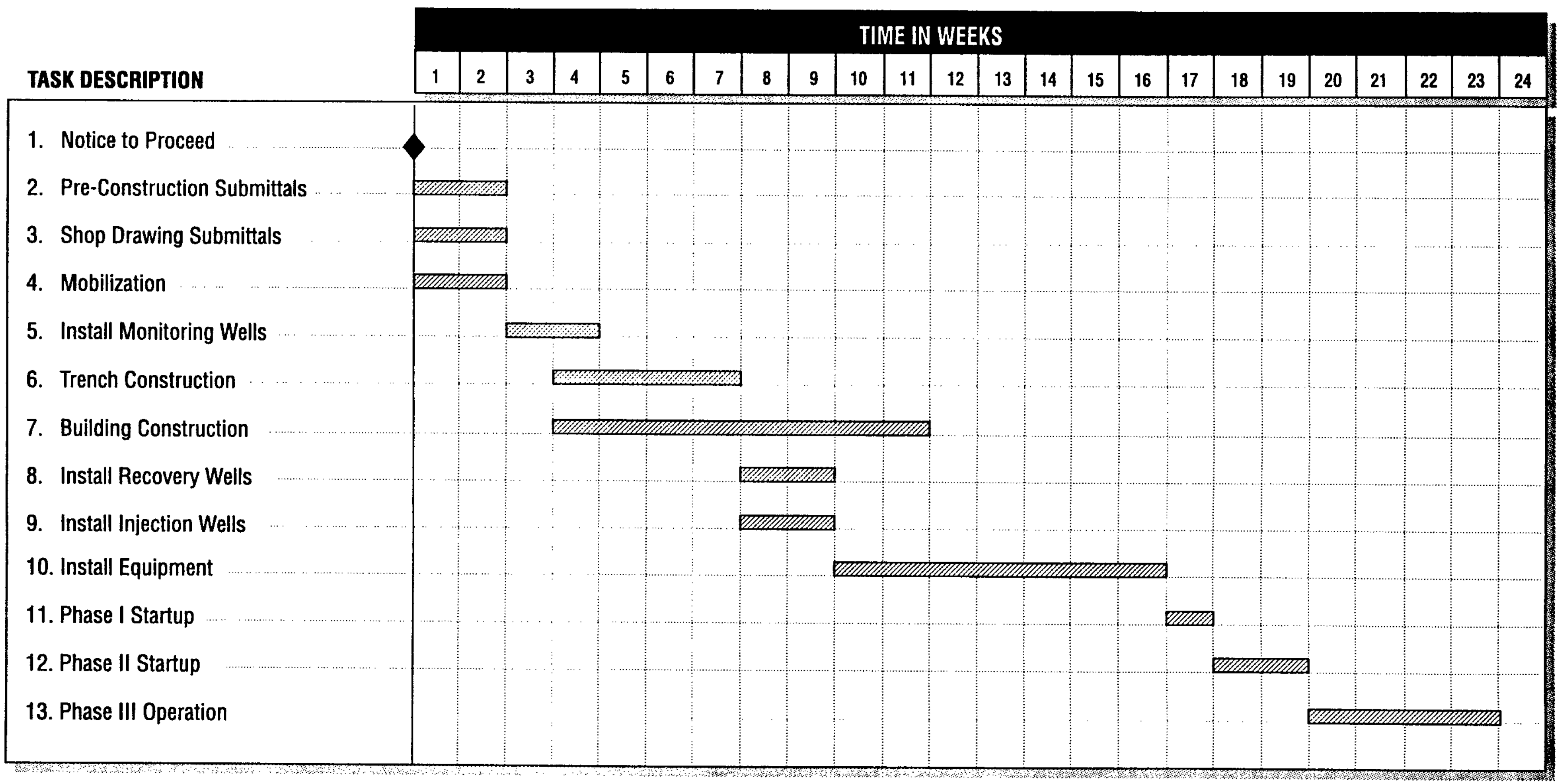

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CONSTRUCTION SCHEDULE
PILOT STUDY - FIRE TRAINING AREA

FIGURE 7-1

APPENDIX A

GROUNDWATER EXTRACTION ANALYSIS

PROJECT: Loring AFB		MADE BY: M.O.	DATE: 12/8/94
SUBJECT: Extraction System		CHKD. BY: FAS	DATE:

1. PURPOSE

This calculation was performed to provide a conceptual plan of the groundwater and product extraction system fort the former fire training area at the Loring AFB.

2. METHODOLOGY

It will be assumed that the area from which the water and product have to be captured is located within a uniform flow field. The groundwater will be extracted in the region immediately downgradient of the plume, and reinjected into the aquifer upgradient of the plume. Assuming that both the extraction and injection take place at localized points, the system can be analyzed as a doublet in a uniform flow.
From Ref 1, Eq 8-177, we have:

$$\phi = -\frac{q_0 B}{T}(x\cos\alpha + y\sin\alpha) + \frac{Q_w}{4\pi T}\ln\frac{(x+d)^2+y^2}{(x-d)^2+y^2}$$

$$\psi = -\frac{q_0 B}{T}(y\cos\alpha - x\sin\alpha) + \frac{Q_w}{2\pi T}\left\{\tan^{-1}\frac{y}{x+d} - \tan^{-1}\frac{y}{x-d}\right\}$$

Where:

- ϕ - Piezometric head, [ft]
- ψ - Stream function, [ft]
- q_0 - Specific discharge(=$K_a i$), [ft/d]
- x,y - Coordinates, [ft]
- α - Angle between positive x and direction of flow, [R]
- Q_w - Extraction rate(=injection rate), [ft^3/d]
- T - Transmissivity(=$K_a B$), [ft^2/d]
- B - Saturated thickness, [ft]
- d - Half of distance between wells, [ft]
- K_a - Hydraulic conductivity, [ft/d]
- i - Hydraulic gradient, [-]

Assuming that the wells are aligned with the flow direction, $\alpha = \pi$ and:

$$\phi = \frac{q_0 B}{T} x + \frac{Q_w}{4\pi T} \ln \frac{(x+d)^2+y^2}{(x-d)^2+y^2}$$

$$\psi = \frac{q_0 B}{T} y + \frac{Q_w}{2\pi T} \{ \tan^{-1} \frac{y}{x+d} - \tan^{-1} \frac{y}{x-d} \}$$

The stagnation points x_s can be located by observing that they occur at the x axis($y = 0$), and at the local max/min of the hydraulic head($d\phi/dx = 0$).

$$\frac{\partial \phi}{\partial x}(x,0) = \frac{q_0 B}{T} - \frac{Q_w d}{\pi T (x^2 - d^2)}$$

$$\frac{\partial \phi}{\partial x}(x,0) = 0 \rightarrow \quad 0 = \frac{q_0 B}{T} - \frac{Q_w d}{\pi T (x^2 - d^2)}$$

$$x^2 - d^2 = \frac{Q_w d}{q_0 B \pi}$$

$$x_s = (+/-)\ d \sqrt{1 + \frac{Q_w}{\pi d q_0 B}}$$

The y coordinate of the dividing streamline at $x = 0$ (y_s) can be calculated by observing that the flow at $x = 0$ is perpendicular to the y axis (no y component), and that the half of the extraction rate has to pass through the y axis between y = 0 and y = y_s.

$$FLOW\ AT\ x{=}0 = \frac{Q_w}{2} = T\int_0^{y_s} \frac{\partial\phi}{\partial x}(0,y)\ dy$$

$$\frac{\partial\phi}{\partial x}(0,y) = \frac{q_0 B}{T} + \frac{Q_w d}{\pi T(d^2+y^2)}$$

$$\frac{Q_w}{2} = T\left[\frac{q_0 B}{T}y + \frac{Q_w d}{\pi T}\frac{1}{d}\tan^{-1}\frac{y}{d}\right]_0^{y_s}$$

$$\frac{Q_w}{2} = T\int_0^{y_s}\left[\frac{q_0 B}{T} + \frac{Q_w d}{\pi T(d^2+y^2)}\right]dy$$

$$\frac{Q_w}{2} = q_0 B y_s + \frac{Q_w}{\pi}\tan^{-1}\frac{y_s}{d}$$

$$Q_w = \frac{q_0 B y_s}{\frac{1}{2} - \frac{1}{\pi}\tan^{-1}\frac{y_s}{d}}$$

This can be solved for y_s iteratively, for example using Newton's method:

$$y_s = \frac{Q_w}{q_0 B}\left(\frac{1}{2} - \frac{1}{\pi}\tan^{-1}\frac{y_s}{d}\right)$$

So, both the width of the doublet ($2y_s$), as well as its length ($2x_s$) can be estimated as a function of the aquifer parameters, well spacing and extraction/injection rate. Alternatively, by setting the desired dimensions of the doublet, the required extraction/injection rate can be calculated.

The above formulae will be used to estimate the extraction/ injection rate required to create a self-enclosed zone around the plume. The rate will be than applied to the conceptual design of the extraction facilities. It will be assumed that the actual extraction will take place inside a long strip of artificially fractured bedrock with several withdrawal wells. This will be treated as acting like a trench, with the wells dividing it into separate stretches. The total extraction rate is converted into the inflow into the trench per its unit length.

From Ref 1, Eq 5-210 we have:

$$K_t \frac{d}{dx}\left(h\frac{dh}{dx}\right) + N = 0$$

Where:

- K_t - Hydraulic conductivity of the trench, [ft/d]
- x - Distance (between 0 and L), [ft]
- h - Hydraulic head, [ft]
- N - Inflow per unit length, [ft/d]

By applying boundary conditions of no flow at the divides between regions tributary to adjacent wells, and constant head h_w at the wells, we have:

$$\frac{dh}{dx}(x=0) = 0 , \qquad h(x=L) = h_w$$

$$h = \sqrt{-\frac{N}{K_t}x^2 + \frac{NL^2}{K_t} + h_w^2}$$

This way, the head distribution between the wells can be found for different assumed values of well spacing.
Next, the feasibility of injection will be evaluated. It was observed that the groundwater table in the vicinity of the upgradient edge of the product plume occurs very close to the bedrock/overburden interface. The overburden deposits are composed mostly of till, which may not be very conductive. As a conservative assumption, the till will be treated as a confining bed for the bedrock aquifer. The injection rate into a well in the confined aquifer can be calculated from(Ref 1, Eq 8-4):

$$Q_w = \frac{2\pi T s_w}{\ln \frac{R}{r_w}}$$

Where:

Q_w - Injection rate, [ft^3/d]
T - Transmissivity, [ft^2/d]
s_w - Buildup in the injection well, [ft]
R - Radius of influence, [ft]
r_w - Radius of the well, [ft]

3. PARAMETERS

The following values of parameters will be assumed:

* **Half of distance between injection and extraction - d**
  From a figure depicting the plume and the flow pattern, it appears that the distance between upgradient and downgradient edges of the plume is approximately 450 ft. See page 10 of this calc. Assume that the facilities are located 75 ft away from edges, at a distance of 600 ft. From this:
  $$d = 600/2 = 300 \text{ ft}$$

* **Half of the width of the doublet - y_s**
  The width of the plume appears to be approximately 250 ft. Assume the required width of the self enclosed zone as 400 ft. From this:
  $$y_s = 400/2 = 200 \text{ ft}$$

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* **Hydraulic conductivity of the aquifer - K_a**
  The representative value of the hydraulic conductivity of the bedrock aquifer is difficult to estimate. The pump test results seem to indicate the transmissivity of between 77 and 530 ft^2/d for the top 60 ft of bedrock. From that, the K value is approximately 5E-4 to 3E-3 cm/s. The results of slug test show values up to the order of E-2 cm/s. As a conservative approach, the value of 1E-2 cm/s will be used
  K_a = 1E-2 cm/s = 28 ft/d => use 30 ft/d

* **Saturated thickness - B**
  The trench is proposed to penetrate the upper 50 ft of the saturated bedrock. Assume that the total depth to which the groundwater will be intersected is 20 ft higher. Use:
  B = 50 + 20 = 70 ft

* **Hydraulic gradient - i**
  From the figure on page 10 of this calculations, assume:
  i = 4.5/450 = 0.01

* **Hydraulic conductivity of the trench - K_t**
  Assume that the trench will be fractured to achieve 5E-2 cm/s. Use:
  K = 140 ft/d

* **Dimensions of the trench**
  The aquifer is composed of fractured media. Assume that in order to capture flow from all fractures, the trench will extend along the entire downgradient edge of the plume. From a figure on page 10 of this calculations, this is approximately 360 ft. Also, assume that the trench will be 5 ft wide.

* **Allowable buildup in the injection well - s_w**
  The thickness of the overburden in the area of study is approximately 20 ft. Use 50% of it as the max. allowable buildup:
  s_w = 0.5*20 = 10 ft

* **Radius of injection well - r_w**
  Assume 6 inch wells.
  r_w = (6/12)*0.5 = 0.25 ft

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* **Radius of influence - R**
  Use Siechardt formula(Ref 1, Eq 8-11). Note that it is expressed in units of "m" and "s":

$$R = 3,000\ s_w\ K_a^{1/2}$$
$$R = 3,000*3*(1E-4)^{1/2} = 90\ m = 300\ ft$$

4. CALCULATIONS

Estimate the flow rate to create a self-enclosed zone of width equal to $2y_s$:

$$q_0 = 30*0.01 = 0.3\ ft/d$$

$$Q_w = 0.3*70*200/[0.5-(1/\pi)\tan^{-1}(200/300)]$$
$$Q_w = 13,425\ ft^3/d$$

Find the distribution of water levels within the trench. Assume 3 wells, dividing the trench into 6 zones of 60 ft length:

$$L = 60\ ft$$

Assume that from the original saturated thickness of 70 ft, 10 ft will be used for the drawdown in the well:

$$h_w = 70 - 10 = 60\ ft$$

Convert the flow rate into the trench into 1-Dimensional inflow per unit length:

$$N = 13,425/(5*360) = 7.5\ ft/d$$

Calculate the maximum saturated thickness within the trench, i.e at x = 0:

$$h_{max} = [(7.5*60^2/140) + 60^2]^{1/2}$$
$$h_{max} = 61.5\ ft$$

This is less than the original saturated thickness of 70 ft. OK.

Calculate the injection rate of a single well.

$$T = 30*70 = 2,100\ ft^2/d$$

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SUBJECT: Extraction System

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$$Q_w = 2*\pi*2,100*10/\ln(175/0.25)$$
$$Q_w = 11,139\ ft^3/d = 58\ gpm$$

Using an allowance of 50% for the capture of downgradient water, the extraction rate would be:

$$Q = 1.5*13,425 = 20,138\ ft^3/d$$
$$Q = 105\ gpm$$

Assume that at least 2 injection wells will be required.

5. CONCLUSIONS

A conceptual plan was developed for the implementation of the extraction/injection system that would capture the product and contaminated groundwater from the eastern plume. It was assumed that the product and water will be intercepted to the depth of 70 feet below the current water table. The extraction will take place via 3 wells placed inside a 360 ft long trench, created at the downgradient edge of the plume by artificially fracturing the bedrock. The treated water will be injected upgradient, using the minimum of 2 injection wells. The flow rate estimated to create a self-enclosed zone around the site is approximately 105 gpm. This was obtained by using a conservative value of the hydraulic conductivity of the bedrock aquifer (i.e. K = 1E-2 cm/s). The actual flow rate may be up to one and a half orders of magnitude lower, if the K value of 5E-4 cm/s (lower limit of the possible range) is used. This is approximately 7 gpm. Assuming twice the geometric mean of the high and low values as the expected rate, the discharge would be on the order of:

$$Q = 2 * (105 * 7)^{1/2} = 2 * 27 = 54\ gpm.$$

Use 60 gpm as an expected value of the required extraction rate.

The western plume is much smaller than the eastern plume. It is expected that, using a similar system to the one outlined above, the extraction rates would be roughly 30% of the rates calculated for the eastern plume(i.e. between 2 and 32 gpm, with the expected value of approximately 15 gpm). It is anticipated that 2 wells placed in a downgradient trench of 150 ft length would be sufficient to extract the desired rate, while 2 injection wells at the upgradient edge should be able to return the treated water to the aquifer.

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SUBJECT:	Extraction System	CHKD. BY: FAS	DATE:

In summary, the treatment of both plumes would require the combined extraction/injection rate of approximately between 10 and 140 gpm(expected 75 gpm), roughly 600 ft of trench created by artificially fracturing bedrock, 5 extraction wells and 4 injection wells.

6. REFERENCES

1. Hydraulics of Groundwater
J. Bear
McGraw-Hill, 1979

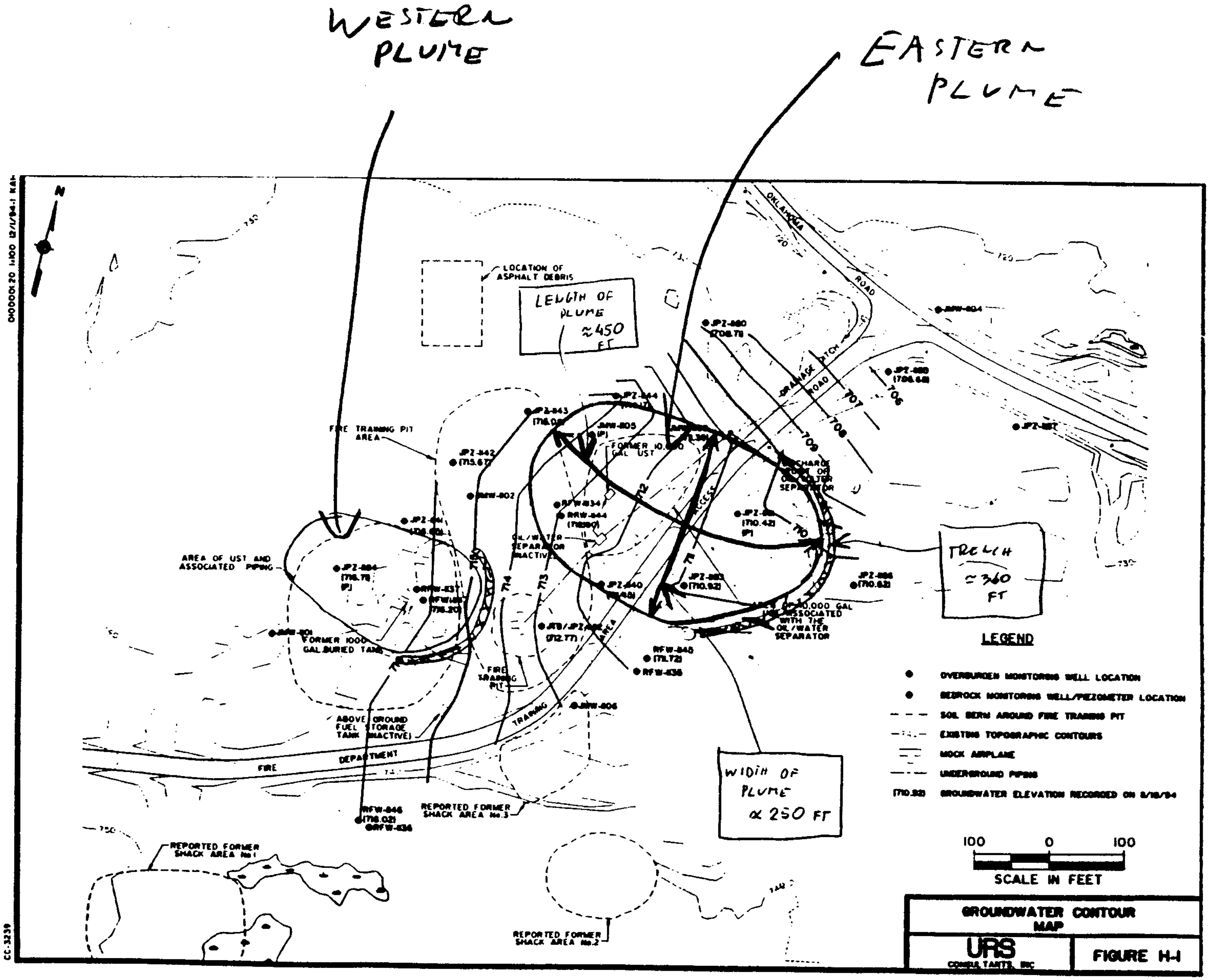
WESTERN PLUME
EASTERN PLUME
LENGTH OF PLUME ≈450 FT
TRENCH ≈360 FT
WIDTH OF PLUME ≈ 250 FT
LOCATION OF ASPHALT DEBRIS
FIRE TRAINING PIT AREA
AREA OF UST AND ASSOCIATED PIPING
FORMER 1000 GAL BURIED TANK
ABOVE GROUND FUEL STORAGE TANK (INACTIVE)
FIRE TRAINING PIT
OIL/WATER SEPARATOR (INACTIVE)
FORMER 10,000 GAL UST
FIRE DEPARTMENT TRAINING
ACCESS
OKLAHOMA ROAD
DRAINAGE DITCH
REPORTED FORMER SHACK AREA No.1
REPORTED FORMER SHACK AREA No.2
REPORTED FORMER SHACK AREA No.3
LEGEND
OVERBURDEN MONITORING WELL LOCATION
BEDROCK MONITORING WELL/PIEZOMETER LOCATION
SOIL BERM AROUND FIRE TRAINING PIT
EXISTING TOPOGRAPHIC CONTOURS
MOCK AIRPLANE
UNDERGROUND PIPING
(710.92) GROUNDWATER ELEVATION RECORDED ON 8/18/94
100 0 100
SCALE IN FEET
GROUNDWATER CONTOUR MAP
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FIGURE H-1
CC-3239

10

(11)

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Sydney
Tokyo
Toronto

Ref 1

JACOB BEAR

Department of Civil Engineering
Technion—Israel Institute of Technology
Haifa
Israel

Hydraulics of Groundwater

12

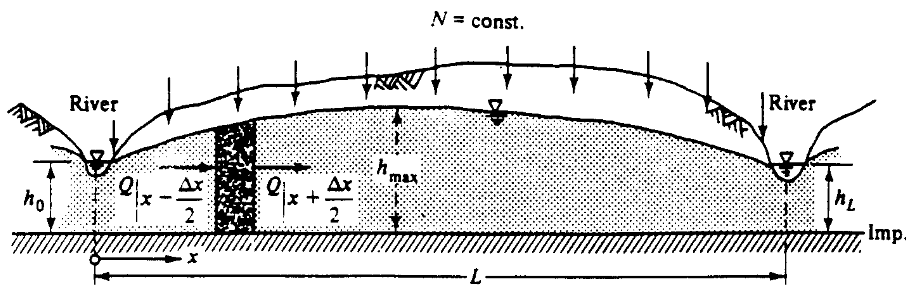


Figure 5-40 Flow in a phreatic aquifer with accretion.

bearing formation we assume that at $x = 0$ and $x = L$ we have vertical equipotentials $\phi = h_0$ ($\ll L$) and $\phi = h_L$ ($\ll L$), respectively, and that everywhere the flow is essentially horizontal. We know that in the vicinity of the water table peak and under the streams this assumption is incorrect (in fact the flow in these places is along the vertical), yet the regions of error are relatively small and the results based on the assumption of horizontal flow should be considered a good estimate for all practical purposes.

The continuity equation is obtained either from (5-70), or from a water balance written for the control box shown in Fig. 5-40

$$Q\Big|_{x-\Delta x/2} + N\,\Delta x - Q\Big|_{x+\Delta x/2} = 0; \qquad -\frac{dQ}{dx} + N = 0;$$

$$\boxed{K\frac{d}{dx}\left(h\frac{dh}{dx}\right) + N = 0} \tag{5-210}$$

By integration, we obtain

$$\frac{Kh^2}{2} + \frac{Nx^2}{2} + C_1x + C_2 = 0 \tag{5-211}$$

Using the boundary conditions $x = 0$, $h = h_0$; $x = L$, $h = h_L$, we obtain

$$C_2 = -\frac{K}{2}h_0^2; \qquad C_1 = -\frac{K}{2L}(h_L^2 - h_0^2) - \frac{NL}{2}$$

Hence

$$K(h^2 - h_0^2) - Nx(L - x) + K\frac{x}{L}(h_0^2 - h_L^2) = 0 \tag{5-212}$$

gives the shape of the water table $h = h(x)$. By differentiating (5-212), we

$$Kh\frac{dh}{dx} \equiv -Q(x) = N\left(\frac{L}{2} - x\right) - \frac{K}{2L}(h_0^2 - h_L^2)$$

By integrating (8-1) from r_w to R, we obtain

$$s_w = H - h_w = \phi(R) - \phi(r_w) = (Q_w/2\pi T)\ln(R/r_w) \tag{8-4}$$

Between any two distances r_1 and $r_2(>r_1)$, we obtain

$$\phi(r_2) - \phi(r_1) = s(r_1) - s(r_2) = (Q_w/2\pi T)\ln(r_2/r_1) \tag{8-5}$$

Equation (8-5) is called the Thiem equation (Thiem, 1906).

Between any two distances r and R, we obtain

$$s(r) = \phi(R) - \phi(r) = (Q_w/2\pi T)\ln(R/r) \tag{8-6}$$

By dividing (8-3) by (8-4), we obtain

$$\phi(r) - h_w = (H - h_w)\frac{\ln(r/r_w)}{\ln(R/r_w)} \tag{8-7}$$

showing that the shape of the curve $\phi = \phi(r)$, given h_w and H at r_w and R, respectively, is independent of Q_w and T.

The distance R in (8-4), (8-6), and (8-7), where the drawdown is zero, is called the *radius of influence of the well*. Since we have established above that steady flow cannot prevail in an infinite aquifer, the distance R should be interpreted as a parameter which indicates the distance beyond which the drawdown is negligible, or unobservable. In general, this parameter has to be estimated from past experience. Fortunately, R appears in (8-6) in the form of $\ln R$ so that even a large error in estimating R does not appreciably affect the drawdown determined by (8-6). The same observation is true also for another parameter—the radius of the well r_w (Sec. 8-1).

Various attempts have been made to relate the radius of influence, R, to well, aquifer, and flow parameters in both steady and unsteady flow in confined and phreatic aquifers. Some relationships are purely empirical, others are semi-empirical. For example (Bear, Zaslavsky, and Irmay, 1968).

Semi-empirical formulas are

Lembke (1886, 1887):	$R = H(K/2N)^{1/2}$,	(8-8)
Weber (Schultze, 1924):	$R = 2.45(HKt/n_e)^{1/2}$,	(8-9)
Kusakin (Aravin and Numerov, 1953):	$R = 1.9(HKt/n_e)^{1/2}$	(8-10)

Empirical formulas are

Siechardt (Chertousov, 1962):	$R = 3000 s_w K^{1/2}$,	(8-11)
Kusakin (Chertousov, 1949):	$R = 575 s_w (HK)^{1/2}$	(8-12)

where R, s_w (= drawdown in pumping well), and H are in meters and K in meters per second.

In phreatic aquifers (Sec. 8-3) N, H, and n_e represent accretion from precipitation, the initial thickness of the saturated layer, and the specific yield (or effective porosity) of the aquifer, respectively. In confined aquifers, H and n_e have to be

13

Example 2 A pumping and recharging pair of wells in uniform flow

Consider a recharging well at $(+d, 0)$ and a pumping well at $(-d, 0)$ in a homogeneous isotropic aquifer in which flow takes place at a constant specific discharge q_0 in a direction making an angle α with the $+x$ axis. Both wells are of equal strength $Q_w = \text{const}$. For this case

$$\left.\begin{aligned}\phi &= -\frac{q_0 B}{T}(x\cos\alpha + y\sin\alpha) + \frac{Q_w}{4\pi T}\ln\frac{(x+d)^2+y^2}{(x-d)^2+y^2}\\ \psi &= -\frac{q_0 B}{T}(y\cos\alpha - x\sin\alpha) + \frac{Q_w}{2\pi T}\left\{\tan^{-1}\frac{y}{x+d} - \tan^{-1}\frac{y}{x-d}\right\}\end{aligned}\right\} \tag{8-177}$$

Several examples of detailed flownets are described in Fig. 8-31 for different values of α. One may observe that under certain conditions (determined by the relationships between q_0, α, and Q_w) no streamline emerging from the recharging well terminates in the pumping well. This means that no injected fluid will ever reach the pumping well. Dacosta and Bennett (1960) study this problem in detail in connection with artificial recharge operations. They also determine the location of stagnation points and the amounts of interflow between the wells by taking twice the difference between the value of ψ passing through the origin of coordinates, and the value of ψ passing through one of the stagnation points (multiplied by K).

The shaded areas in Fig. 8-31 (pages 371–372) indicate regions of interflow. Groundwater divides and stagnation points can easily be determined for each case from (8-177).

The situations shown in Figs. 8-31a through d are not the only possible ones for the respective cases. As already indicated above, the resulting flownet depends in each case on the relationships between q_0, α and Q_w, with a possibility of different values of Q_w for the two wells. To illustrate this point, let us consider the case shown in Fig. 8-31a in which the shaded diamond-shaped area shows where recirculation takes place between the wells (with the pumping well located upstream of the recharging one). If however, the distance between the wells is made sufficiently large for a given well discharge, Q_w (equal to the rate of recharge) and a uniform specific discharge q_0, recirculation can be prevented entirely. This case is shown in Fig. 8-32a. As pumping and recharging rates increase, for the same distance, $2d$, and uniform specific discharge, q_0, a value of Q_w is reached such that the uniform groundwater flow is just balanced by the opposing flows produced by the two wells at a point midway between them (again for equal values of pumping and recharge) as shown in Fig. 8-31b. A further increase in Q_w will then produce the situation shown in Fig. 8-32a. In order to obtain the critical value of Q_w we have to equate q_0 to the sum of the specific discharges induced by the two wells at that point

$$q_0 = \frac{Q_w}{2\pi dB} + \frac{Q_w}{2\pi dB} = \frac{Q_w}{\pi dB} \tag{8-178}$$

APPENDIX B

TREATMENT SYSTEM DESIGN CALCULATIONS

EXHIBIT 5.5-2

URS Consultants, Inc.
CALCULATION COVER SHEET

Client: ____________ Project Name: Loring AFB OU-8 Pilot Study Design

Project/Calculation Number: ____________

Title: Calculation of TDH for groundwater and product recovery pumps

Total number of pages (including cover sheet): 4

Total number of computer runs: -0-

Prepared by: Martin J Wesolowski Date: 12/5/94

Checked by: Frank A Silvernail Date: 12/8/94

Description and Purpose:

To determine total head requirements and pump size for groundwater and product recovery pumps.

Design bases/references/assumptions:

references: 1) Ejector Systems, Pneumatic Ejectors: Pumping Contaminated Ground water, Recovering Hydrocarbons and Extracting Leachate, 1993, Pgs 35-40.

2) IngersollRand, Cameron Hydraulic Data, 1984 Pg 1-27

3) Bertin, J.I Engineering Fluid Mechanics, 1987 Pgs 269-308

Remarks/conclusions:

groundwater pump = use 2hp pump @ 50 gpm and 75 TDH

product pump = use

Calculation Approved by: ____________

Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

Project Manager/Date

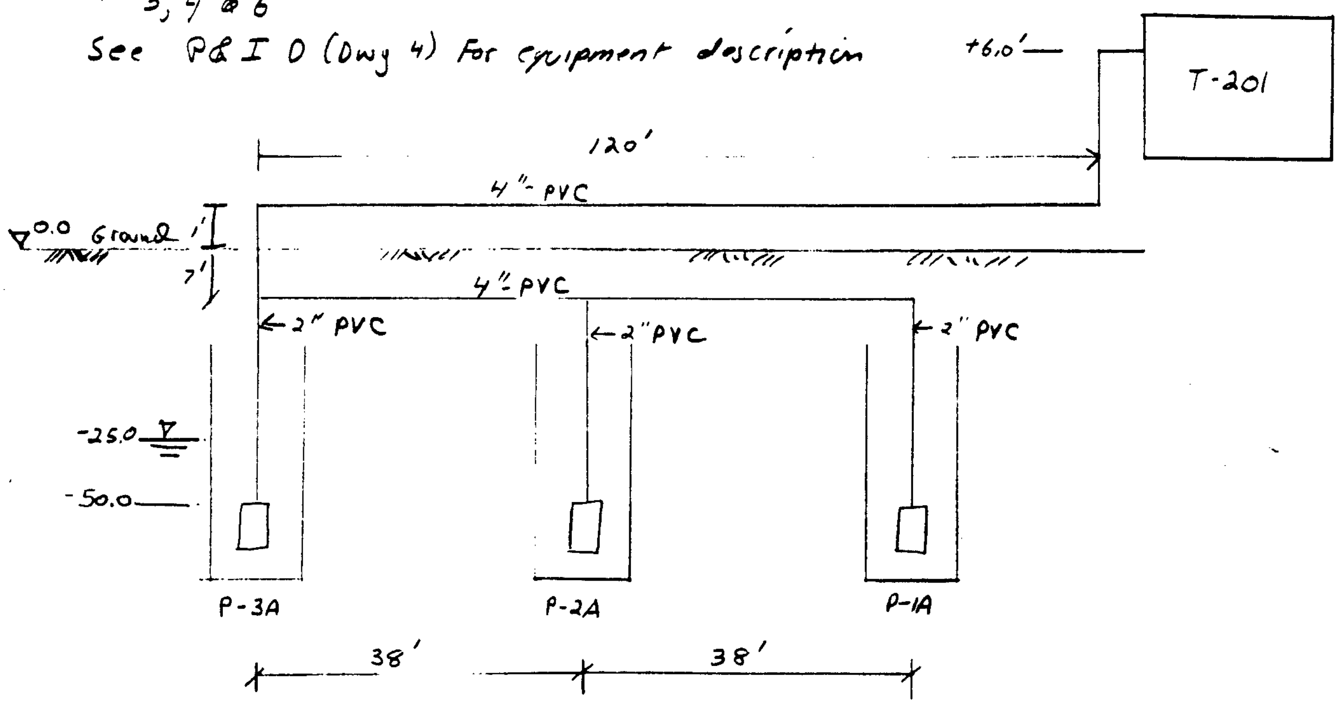
URS CONSULTANTS, INC.

PROJECT Loring AFB - OU 8
SUBJECT Remedial Design - Pilot Study
TDH Calculation - Submersibles

JOB NO. 01 00001 06205
MADE BY MLW DATE 12/5/94
CHKD. BY FAC DATE 12/8/94

REF. PAGE

All dimensions based on Design drawings. see drawings # 3, 4 & 6
See P&ID (Dwg 4) For equipment description



Q = 50 GPM Per well (Assumed max flow per well)

For pipe head loss Assume Sch 40 ST. pipe ≥ Sch 40 PVC pipe

Pipe head loss (Based of Sch 40 ST pipe) (Ref #1)

2"ø @ 50 gpm = 4.67 ft/100 ft
4"ø @ 50 gpm = .194 ft/100 ft
4"ø @ 100 gpm = .719 FT/100 FT
4"ø @ 150 gpm = 1.57 FT/100 FT

Equivalent lengths of straight pipe for fittings (Ref #1)

2" valve = 1.5 ft
2" elbow = 8.5 ft
4" Tee = 21 ft
4' elbow = 13 ft
2" check valve = 19 ft

PROJECT Loring AFB - OU 8
SUBJECT Remedial Design - Pilot Study
TDH Calculation

REF. PAGE

P-1A

static Lift = 56'

equivalents = 60'(2"ø) x 4.67 ft/100ft + 1.5(1valve) + 8.5x2(2 elbows) + 196'(4"ø) x .194 ft/100ft + 13x5(5 elbows) + 21 (Tee) = 108'

=> 108'/100 ft = 1.1'

Total Head Loss = 57.1 + 1.3 FS = 74.2 => Say 75'

(Assume 1.3 Factor of Safety (FS))

P-3A

static Lift = 56'

equivalents = 60'(2"ø) x 4.67 ft/100 ft + 1.5(1valve) + 8.5 x 2(2 elbows) + 120'(4"ø) x 1.57 ft/100 ft + 13x4(elbows) = 75'/100' = .75

Total Head loss = 56.8 + 1.3 FS = 73.8 => say 75'

$$TDH(P\text{-}2A) = \frac{75 + 75}{2} = 75 \text{ ft}$$

$$BHP = \frac{50 \times 75 \times 1}{3960 \times .6} = 1.6 \Rightarrow \text{say } 2\text{Hp}$$

$$\text{Brake hp (BHP)} = \frac{\text{gpm} \times TDH \times sp\,gr}{3960 \times \text{efficiency}}$$ (Ref 2)

REF. PAGE

Skimmers P-1B, 2B & 3B - use Layout Dwg for Pumps P-1A, 2A & 3A

Q = 0.5 GPM per well (Assume)

Static Lift = 25' (from water surface) + 10' (to product tank T-210) = 35'

For pipe head loss:

$$h_f = f\,L/D\;V^2/2g$$

h_f = Friction loss in feet of liquid
f = friction factor
L = Length of pipe
D = average internal diameter of pipe in feet
V = average velocity in pipe in feet per second
g = acceleration due to gravity in feet per second

f = .012
L = 120 ft
D = 0.167 ft
V = .5 GPM = 3 ft/s
g = 32.2 ft/s

$$h_f = .012\ \frac{120}{0.167}\left(\frac{(3)^2}{2(32.2)}\right) = 1.2\ ft$$

TDH = 35' + 1.2' = 36.2' x 1.7 FS = 61.54 => say 60 ft

Allow 1.7 FS for losses in bends, Tee, inlet, outlet, ect.

Pump = 0.5 gpm @ 60 ft TDH

EXHIBIT 5.5-2

URS Consultants, Inc.
CALCULATION COVER SHEET

Client: ________ Project Name: Loring AFB OU-8 Pilot Study Design

Project/Calculation Number: ________

Title: Calculation of TDH for discharge pump P-301

Total number of pages (including cover sheet): 2

Total number of computer runs: -0-

Prepared by: Martin J Wesolowski Date: 12/7/94

Checked by: Frank A Silvernail Date: 12/8/94

Description and Purpose:

To determine total head requirements and pump size for discharge pump P-301.

Design bases/references/assumptions:

References: 1) Ejector Systems, Pneumatic Ejectors: Pumping Contaminated Groundwater Recovering Hydrocarbons and Extracting Leachate, 1993 Pgs 35-40

2) Ingersoll rand, Cameron Hydraulic Data, 1984 Pg 1-27

Remarks/conclusions:

TDH = 100' @ 175 gpm

Calculation Approved by: ________

Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

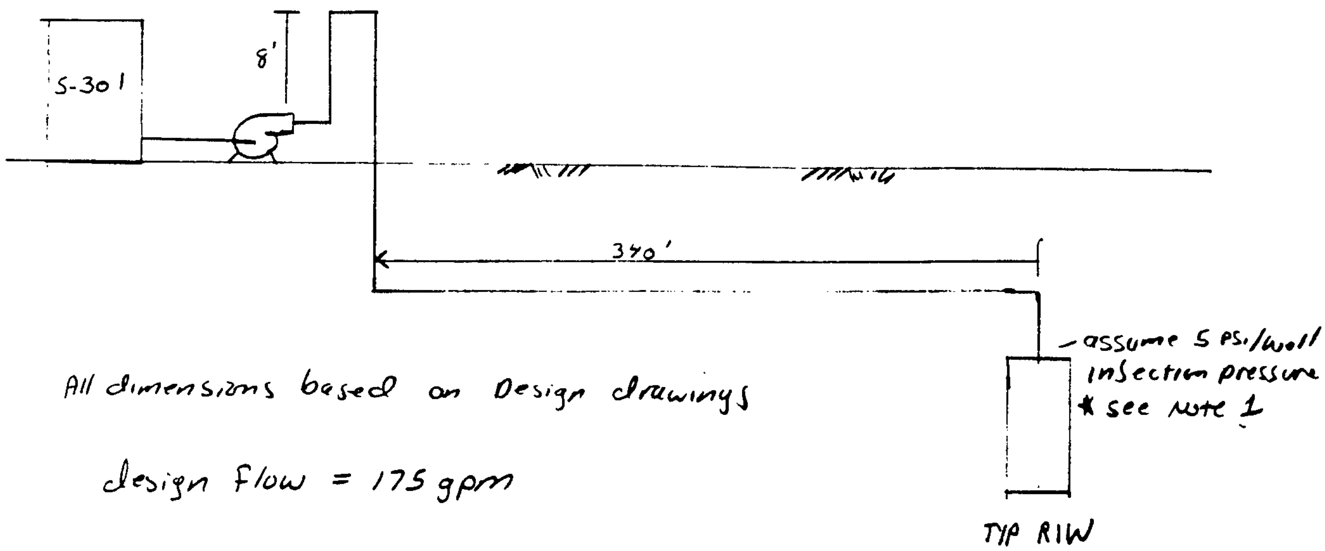
Project Manager/Date

URS CONSULTANTS, INC.

PAGE 1 OF 1
SHEET NO. 1 OF 1
JOB NO. 01.00001.06205
MADE BY MJ DATE 12/7/94
CHKD. BY .... DATE ....

PROJECT Loring AFB: OU8
SUBJECT Remedial Design - Pilot Study
TDH Calculation - Discharge pump

REF. PAGE



All dimensions based on Design drawings

design flow = 175 gpm

For pipe head loss assume sch 40 st pipe ≥ sch 40 PVC pipe loss
pipe loss based on sch 40 ST pipe

For 4" Ø @ 175 gpm = 1.7 Ft/100 FT (Ref #1)

Equivalent lengths of straight pipe for fittings (Ref #1)

4" Tee = 21 ft
4" elbow = 13 ft

Note 1: Calculations for reinjection indicate that each well will handle 58 gpm flow under gravity conditions 5psi allowed for lower than expected flow.

Static Lift = 8' + 5psi/0.433 5 (3 wells) = 43'

losses = 340' × 1.7/100 + [9 elbows (13') + 1 tee (21)]/100 = 7.16

total Head = 50.16

Allow 50% Factor of Safety for unexpected Conditions

TDH = 100'

EXHIBIT 5.5-2

URS Consultants, Inc.
CALCULATION COVER SHEET

Client: ____________ Project Name: Loring AFB OU-8

Project/Calculation Number: ____________

Title: Calculation of Ventilation and heating requirements

Total number of pages (including cover sheet): 5

Total number of computer runs: -0-

Prepared by: Martin S Wesolowski Date: 12/2/94

Checked by: Frank A Silvernail Date: 12/8/94

Description and Purpose:

Calculation of ventilation and heating requirements

Design bases/references/assumptions:

Reference: 1) American Conference of Governmental Industrial Hygienists, Industrial Ventilation: A Manual of Practice, 16th edition

Remarks/conclusions:

Calculation Approved by: ____________

Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

Project Manager/Date

URS CONSULTANTS, INC.

PAGE 1 OF 2
SHEET NO. 1 OF 2
JOB NO. 01.00001.06205
MADE BY MLW DATE 12/2/94
CHKD. BY FAS DATE 12/8/94

PROJECT Loring AFB OU-8
SUBJECT Remedial Design - Pilot Study
Ventilation

REF. PAGE

Cooling Fan

Required air movement = 15-25 Fpm per Ref #1

Building Dimensions (interior) 50'L X 20W X 16'H

Air Flow Rate Required for Cooling (Assume 15 FPM)

$20' \times 16' \times 20'/min = 6400\ cfm$

Assume $\Delta P = .25 in$

Louver For Air Inlet

Louver Intake Velocity = 700 FPM

$6400\ CFm - 800\ CFm\ (\text{Roof Fan}) \div 700\ FPM = 8.0\ Ft^2$

Use 48" X 48" Louver @ $8.51\ Ft^2$

Ventilation Fan

$50' \times 20' \times 16' \times \frac{3\ \text{Changes}}{hr} \times \frac{hr}{60 min} = 800\ CFM$

Louver For Cooling Fan outlet

Required Air Flow Discharge Rate = 5600 cfm

5600 cfm ÷ 700 FPM = 8.0 Ft^2

Use 48" x 48" Louver @ 8.51 Ft^2

URS CONSULTANTS, INC.

PAGE 1 OF 2
SHEET NO. 1 OF 2
JOB NO. 01.00001.06205
MADE BY MLW DATE 12/2/94
CHKD. BY FAS DATE 12/8/94

PROJECT Loring AFB OU-8
SUBJECT Remedial Design - Pilot Study
Heating

REF. PAGE

Building Dimensions 50'L x 20'W x 18'H
Desired Inside Temperature = 50°F
Outside Design Temperature = -20 °F

HEAT LOSS

1) Ventilation Fan: 800 CFM x 60 min/hr x 0.019 BTU/ft^3°F x (50° - (-20)°F)

= 63,840 BTU/hr

2) Heat Loss from Roof = 0.033 BTU/hr FT^2 °F x (50 x 20) x (70°F)
Assume R-30 insulation => U = 1/30 = 0.033
= 2,310 BTU/hr

3) Heat Loss From Walls = 0.091 BTU/hr FT^2 °F x [(50 + 50 + 20 + 20) x 18'] x (70°F)
Assume R-11 insulation => U = 1/11 = 0.091
= 16,052 BTU/hr

4) Heat Loss From Slab = 0.2 BTU/hr FT^2 °F x (50 x 20) x 70°F
With edge insulation assume R-5 value => U = 0.2
= 14,000 BTU/hr

Total Heat Loss = 63,840 + 2,310 + 16,052 + 14 000 = 96202 Btu/hr

96,202 BTU/hr / 3413 KW/BTU/hr = 28.2 KW

Say 30 KW

USE Three (3) 10 KW Unit Heaters @ 34,150 BTU/hr

URS CONSULTANTS, INC.

PROJECT Loring AFB - 048
SUBJECT Remedial Design - Pilot Study
DUCT HEATER

JOB NO. 01.0000.06205
MADE BY M.L. DATE 12/2/94
CHKD. BY FAS DATE 12/8/94

REF. PAGE

AH-301

Outside air design temperature = 0°F

Desired air Temperature = 40°F

Blower Capacity = 1800 CFM

Heat Required = 1800 CFm x 60min/hr X 0.019 BTU/Ft³°F (40-0)°F

≅ 82,080 BTU/hr

$$\frac{82080 \text{ BTU/hr}}{3413 \text{ Kw BTU/hr}} = 24 \text{ KW}$$

URS Consultants, Inc.
CALCULATION COVER SHEET

Client: ____________ Project Name: LORING AFB OU-8 PILOT STUDY DESIGN

Project/Calculation Number: AIR STRIPPER

Title: AIR STRIPPER SIZING CALUCATION

Total number of pages (including cover sheet): ____________

Total number of computer runs: ____________

Prepared by: RONALD P. TRAMPOSCH Date: 12/12/94

Checked by: KEN PODSIADLO Date: 12/13/94

Description and Purpose:

CALCULATION TO DETERMINE AIR STRIPPER UNIT SIZE.

Design bases/references/assumptions:

CALCULATION PERFORMED USING NORTH EAST ENVIRONMENTAL PRODUCTS "SHALLOW TRAY MODELER" SOFTWARE VERSION 1.41

Remarks/conclusions:

Calculation Approved by: ____________

Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

Project Manager/Date

The sizing of the air stripper for the groundwater treatment system was performed utilizing the North East Environmental Products "Shallow Tray Modeler" software version 1.41. Input data consisted of all volatile contaminants as presented in health risk assessment section of the Draft Final Remedial Investigation for the Fire Training Area dated August, 1994. The contaminant level used in the model consisted of the mean of all samples in which the compound was detected.

Design parameters for the air stripper consisted of the following:

Water flow rate - 150 gallons per minute
Water influent temperature - 55 degrees F
Air temperature - 65 degrees F
Safety factor -20%

The results of the model are the following

Air flow - 1800 cfm
Air/Water ratio - 89.8 cu. ft/cu.ft
Minimum of three trays

All effluent levels for volatile contaminants are below the MCL's and MCLG's as presented in the Health Risk Assessment.

The calculations are attached for reference.

URS CONSULTANTS, INC.

PAGE 1 OF 1
SHEET NO. .... OF ....
JOB NO. ....
MADE BY KEP DATE 12/12/94
CHKD. BY R.P.T. DATE 12/13/94

PROJECT Loring Air Force Base - FT Pilot Study
SUBJECT Determination of Air Emissions in ug/M3 for Air Stripper - Model 31231

REF. PAGE

Contaminant	Air (lbs/hr)
Chloromethane	0.000900
Vinyl Chloride	0.000825
1,1-Dichloroethane	0.000900
Chloroform	0.000899
1,1,1-Trichloroethane	0.000825
Carbon Tetrachloride	0.000975
1,1,2-Trichloroethane	0.000825
Benzene	0.001197
Toluene	0.001495
Chlorobenzene	0.000821
Ethyl Benzene	0.004417
Styrene	0.000600
p-Xylene	0.016657
Other (as Benzene)	0.004264
total:	0.035600

$$0.035600 \frac{\text{lbs}}{\text{hr}} \Bigg| \frac{453.6\times10^{6}\ \mu g}{\text{lb}} \Bigg| = 1.615\times10^{7} \frac{\mu g}{\text{hr}}$$

Flow rate of $1800 \frac{ft^3}{Min} \Bigg| \frac{60\,Min}{hr} \Bigg| \frac{0.02832\ M^3}{ft^3} \Bigg| = 3{,}085 \frac{M^3}{hr}$

$$1.615\times10^{7} \frac{\mu g}{hr} \Bigg| \frac{1\ hr}{3{,}085\ M^3} \Bigg| = 5{,}234 \frac{\mu g}{M^3}$$

HUMAN HEALTH RISK ASSESSMENT
FIRE TRAINING AREA

OPERABLE UNIT 8 RI REPORT
LORING AIR FORCE BASE

Compound	Range Of SQLs	Frequency Of Detection	Minimum Detected Concentration	Maximum Detected Concentration	Mean Of All Samples	Background	MCL	MCLG	CPC?	Notes
Fire Training Area Groundwater - 1993 (mg/L)										
Chloromethane	0.001 - 0.1	1 / 17	0.0007	0.0007	0.012			0.003	N	
Vinyl Chloride	0.0001 - 0.0001	3 / 17	0.0001	0.0007	0.011		0.002	0.0001	Y	MEG (8)
1,1-Dichloroethane	0.001 - 0.1	1 / 17	0.0005	0.0005	0.012			0.005	N	
Chloroform	0.001 - 0.1	1 / 17	0.004	0.004	0.012		0.1		N	
2-Butanone	0.004 - 0.5	2 / 17	0.004	0.008	0.057			0.17	N	
1,1,1-Trichloroethane	0.001 - 0.1	1 / 17	0.0002	0.0002	0.011		0.2	0.2	N	
Carbon Tetrachloride	0.001 - 0.1	2 / 17	0.004	0.024	0.013		0.005	0.0027	Y	MEG (7) AND MEG (8)
Trichloroethene	0.001 - 0.1	2 / 17	0.0008	0.005	0.012		0.005	0.005	N	
Benzene	0.001 - 0.1	11 / 17	0.0004	0.089	0.016		0.005	0.005	Y	
4-Methyl-2-Pentanone	0.004 - 0.5	1 / 17	0.32	0.32	0.061				N	No Standard (9)
Toluene	0.001 - 0.1	7 / 17	0.0002	0.19	0.020		1	1.4	N	
Chlorobenzene	0.001 - 0.1	1 / 17	0.0003	0.0003	0.011		0.1	0.047	N	
Ethylbenzene	0.001 - 0.001	12 / 17	0.001	0.2	0.059		0.7	0.7	N	
Styrene	0.001 - 0.1	2 / 17	0.0002	0.011	0.012		0.1	0.005	Y	MEG (8)
Total Xylenes	0.001 - 0.001	12 / 17	0.0004	0.85	0.223		10	0.6	Y	MEG (8)
Phenol	0.01 - 0.1	1 / 17	0.04	0.04	0.012				N	No Standard (9)
4-Methylphenol	0.01 - 0.1	3 / 17	0.002	0.16	0.019				N	No Standard (9)
2,4-Dimethylphenol	0.01 - 0.1	3 / 17	0.004	0.009	0.013				N	No Standard (9)
Naphthalene	0.01 - 0.01	10 / 17	0.014	0.12	0.030			0.025	Y	MEG (8)
2-Methylnaphthalene	0.01 - 0.01	11 / 17	0.001	0.2	0.046				N	
Fluorene	0.01 - 0.1	1 / 17	0.001	0.001	0.013				N	
Phenanthrene	0.01 - 0.1	2 / 17	0.001	0.013	0.013				N	
Pyrene	0.01 - 0.1	1 / 17	0.002	0.002	0.013				N	
bis(2-Ethylhexyl)phthalate	0.01 - 0.24	1 / 17	1.2	1.2	0.090		0.006	0.025	Y	MCL (7) and MEG (8)
alpha-BHC	0.000005 - 0.000024	3 / 16	0.0000036	0.0000082	0.0000062				N	No Standard (9)
beta-BHC	0.000005 - 0.000024	1 / 15	0.000044	0.000044	0.0000078				N	No Standard (9)
gamma-BHC (Lindane)	0.000005 - 0.000024	2 / 15	0.0000032	0.000046	0.000008		0.0002	0.0002	N	
Aldrin	0.000005 - 0.000024	1 / 15	0.0000033	0.0000033	0.0000057				N	No Standard (9)
Endosulfan II	0.00001 - 0.00005	1 / 15	0.000043	0.000043	0.0000129				N	No Standard (9)
4,4'-DDD	0.00001 - 0.00005	1 / 16	0.00059	0.00059	0.0000478				N	No Standard (9)
4,4'-DDE	0.00001 - 0.00005	1 / 16	0.000023	0.000023	0.000012				N	No Standard (9)

ShallowTray
low profile air strippers

System Performance Estimate

Client and Proposal Information:

Loring Air Force Base
Fire Training Area
Pilot Study

Model Chosen:	31200
Water Flow Rate:	150.0 gpm
Air Flow Rate:	1800 cfm
Water Temp:	55.0 F
Air Temp:	65.0 F
A/W Ratio:	89.8 cu. ft/ cu. ft
Safety Factor:	20%

Contaminant	Untreated Influent	Model 31211 Effluent Water Air(lbs/hr) % removal	Model 31221 Effluent Water Air(lbs/hr) % removal	Model 31231 Effluent Water Air(lbs/hr) % removal
Chloromethane	12 ppb	1 ppb 0.000825 92.5171%	<1 ppb 0.000896 99.5334%	<1 ppb 0.000900 99.9709%
Vinyl Chloride	11 ppb	<1 ppb 0.000811 98.2285%	<1 ppb 0.000825 99.9738%	<1 ppb 0.000825 99.9996%
1,1-Dichloroethane	12 ppb	2 ppb 0.000750 89.4712%	<1 ppb 0.000892 99.0762%	<1 ppb 0.000900 99.9189%
Chloroform	12 ppb	2 ppb 0.000750 86.5078%	<1 ppb 0.000887 98.4830%	<1 ppb 0.000899 99.8294%
1,1,1-Trichloroethane	11 ppb	1 ppb 0.000750 93.0125%	<1 ppb 0.000822 99.5931%	<1 ppb 0.000825 99.9763%
Carbon Tetrachloride	13 ppb	1 ppb 0.000900 96.0434%	<1 ppb 0.000974 99.8695%	<1 ppb 0.000975 99.9957%
1,1,2-Trichloroethane	12 ppb	5 ppb 0.000525 64.0364%	2 ppb 0.000750 89.2218%	1 ppb 0.000825 96.7698%
Benzene	16 ppb	3 ppb 0.000975 83.8607%	1 ppb 0.001125 97.8294%	<1 ppb 0.001197 99.7081%
Toluene	20 ppb	4 ppb 0.001201 82.1269%	1 ppb 0.001426 97.3379%	<1 ppb 0.001495 99.6035%

Contaminant	Influent	Model 31211 Effluent Water Air(lbs/hr) % removal	Model 31221 Effluent Water Air(lbs/hr) % removal	Model 31231 Effluent Water Air(lbs/hr) % removal
Chlorobenzene	11 ppb	3 ppb 0.000600 80.4564%	1 ppb 0.000750 96.8171%	<1 ppb 0.000821 99.4816%
Ethyl Benzene	59 ppb	9 ppb 0.003752 85.1837%	2 ppb 0.004277 98.1707%	<1 ppb 0.004417 99.7741%
Styrene	12 ppb	9 ppb 0.000225 28.6727%	6 ppb 0.000450 57.6035%	4 ppb 0.000600 74.7998%
p-Xylene	223 ppb	32 ppb 0.014331 85.7375%	4 ppb 0.016432 98.3048%	1 ppb 0.016657 99.7985%
Other (as Benzene)	57 ppb	10 ppb 0.003527 83.8607%	2 ppb 0.004127 97.8294%	<1 ppb 0.004264 99.7081%

This report has been generated by ShallowTray Modeler software version 1.4.1. This software is designed to assist a skilled operator in predicting the performance of a ShallowTray air stripping system. The software will accurately predict the system performance when both the equipment and the software are operated according to the written documentation and standard operation. North East Environmental Products, Inc. cannot be responsible for incidental or consequential damages resulting from the improper operation of either the software or the air stripping equipment. Report generated: 12/9/1994

>

Code of Maine Rules

06-096 Department of Environmental Protection Bureau of Air Quality Control

Chapter 110 Ambient Air Quality Standards

>

1. Scope.

A. These standards are applicable in all ambient air quality control regions of the State of Maine.

B. All ambient air quality standards are expressed at 25 degrees centigrade and 760 millimeters of mercury pressure.

>

2. Particulate Matter Ambient Air Quality Standards.

A. The level of the 24-hour particulate matter ambient air quality standard is 150 micrograms per cubic meter, as measured in the ambient air as PM_{10}, based on methods contained in Appendix J of 40 CFR Part 50.

The standards are attained when the expected number of days per calendar year with a 24-hour average concentration above 150 ug/m^3, as determined in accordance with Appendix K of 40 CFR Part 50, is equal to or less than one.

B. The level of the annual standard for particulate matter is 40 micrograms per cubic meter, as measured in the ambient air as PM_{10}, based on methods contained in Appendix J of 40 CFR Part 50.

The standards are attained when the expected annual arithmetic mean concentration, as determined in accordance with Appendix K of 40 CFR Part 50, is less than or equal to 40 ug/m^3.

>

3. Sulfur Dioxide Ambient Air Quality Standards.

A. Sulfur dioxide concentration for any 3-hour period at any location shall not exceed 1150 micrograms per cubic meter, except once per year.

B. Sulfur dioxide concentration for any 24-hour period at any location shall not exceed 230 micrograms per cubic meter, except once per year.

C. The annual arithmetic mean of the 24 hour average sulfur dioxide concentrations at any location shall not exceed 57 micrograms per cubic meter.

>
4. Carbon Monoxide Ambient Air Quality Standards.

A. The maximum carbon monoxide concentration for any 8 hour period at any location shall be 10 milligrams per cubic meter, which standard may be exceeded once per year.

B. The maximum carbon monoxide concentration for any 1 hour period at any location shall be 40 milligrams per cubic meter, which standard may be exceeded once per year.

>
5. Photochemical Oxidant Ambient Air Quality Standard.

A. The maximum photochemical oxidant concentration for any 1 hour period at any location shall be 160 micrograms per cubic meter, which standard may be exceeded once per year.

>
6. Hydrocarbon Ambient Air Quality Standard.

A. The maximum hydrocarbon concentration for any 3 hour period at any location shall be 160 micrograms per cubic meter, which standard may be exceeded once per year.

>
7. Nitrogen Dioxide Ambient Air Quality Standard.

A. The annual arithmetic mean of the 24 hour average nitrogen dioxide concentration at any location shall not exceed 100 micrograms per cubic meter.

>
8. Lead Ambient Air Quality Standard.

A. The maximum 24-hour lead concentration at any location shall not exceed 1.5 micrograms per cubic meter except once per year.

>
9. [Reserved]

>
10. Establishment of Ambient Increments.

A. In addition to the ambient air quality standards adopted by the Board and enacted as 38 M.R.S.A., 584-A, any Class I Region or part thereof within the State (including those federal lands designated by the Clean Air Act Amendments of 1977 shall be subject to a maximum allowable increase in concentration of sulfur dioxide and total suspended particulate and Nitrogen Dioxide over the baseline concentration of such pollutants. The maximum allowable increase for any period other than an annual period, shall not be exceeded more than once annually. Such maximum allowable increase shall consist of:

1. Total Suspended Particulate.

a. An increase in the annual geometric mean at any location shall not exceed 5 micrograms per cubic meter.

b. An increase in concentration for any 24-hour period at any location shall not exceed 10 micrograms per cubic meter.

2. Sulfur Dioxide

a. An increase in the annual arithmetic mean at any location shall not exceed 2 micrograms per cubic meter.

b. An increase in concentration for any 24-hour period at any location shall not exceed 5 micrograms per cubic meter.

c. An increase in concentration for any three-hour period at any location shall not exceed 25 micrograms per cubic meter.

3. Nitrogen Dioxide.

a. An increase in the annual arithmetic mean at any location shall not exceed 25 micrograms per cubic meter.

B. In addition to the ambient air quality standards adopted by the Board and enacted as 38 M.R.S.A., 584-A, any Class II region or part thereof within the State shall be subject to a maximum allowable increase in concentration of total suspended particulate, sulfur dioxide and nitrogen dioxide over the baseline concentration of such pollutants. The maximum allowable increase for any period other than an annual period, shall not be exceeded more than once annually. Such maximum allowable increase shall consist of:

1. Total Suspended Particulate.

a. An increase in the annual geometric mean at any location shall not exceed 19 micrograms per cubic meter.

b. An increase in concentration for any 24-hour period at any location shall not exceed 37 micrograms per cubic meter.

2. Sulfur dioxide.

a. An increase in the annual arithmetic mean at any location shall not exceed 20 micrograms per cubic meter.

b. An increase in concentration for any 24-hour period at any location shall not exceed 91 micrograms per cubic meter.

c. An increase in concentration for any three-hour period at any location shall not exceed 512 micrograms per cubic meter.

3. Nitrogen Dioxide.

a. An increase in the annual arithmetic mean at any location shall not exceed 25 micrograms per cubic meter.

C. In addition to the ambient air quality standards adopted by the Board and enacted as 38 M.R.S.A., 584-A, any Class III region or part thereof within the State shall be subject to a maximum allowable increase in concentration of total suspended particulate, sulfur dioxide and nitrogen dioxide over the baseline concentration of such pollutants. The maximum allowable increase for any period other than an annual period, shall not be exceeded more than once annually. Such maximum allowable income increase shall consist of:

1. Total Suspended Particulate.

a. An increase in the annual geometric mean at any location shall not exceed 37 micrograms per cubic meter.

b. An increase in concentration for any 24-hour period at any location shall not exceed 75 micrograms per cubic meter.

2. Sulfur dioxide.

a. An increase in the annual arithmetic mean at any location shall not exceed 40 micrograms per cubic meter.

b. An increase in concentration for any 24-hour period at any location shall not exceed 182 micrograms per cubic meter.

c. An increase in concentration for any three-hour period at any location shall not exceed 700 micrograms per cubic meter.

3. Nitrogen Dioxide.

a. An increase in the annual arithmetic mean at any location shall not exceed 50 micrograms per cubic meter.

>

11. Exclusions From the Increment.

A. Concentrations of such pollutant attributable to the increase in emissions from stationary sources which have converted from the use of petroleum products, or natural gas, or both, by reason of an order which is in effect under the provisions of sections 2(a) and (b) of the Federal Energy Supply and Environmental Coordination Act of 1974 over the emissions from such sources before the effective date of such order;

B. Concentrations of total suspended particulate attributable to the increase in emissions from construction or other temporary emission-related activities; and

C. The increase in concentrations attributable to new sources outside the United States over the concentrations attributable to existing sources which are included in the baseline concentration.

>

12. Chromium.

A. Until such time that an analytical procedure for measuring hexavalent chromium in the ambient air is approved:

1. The maximum 24-hour Total Chromium concentration at any location shall not exceed 0.3 micrograms per cubic meter, and;

2. The annual geometric mean of the Total Chromium concentrations at any location shall not exceed 0.05 micrograms per cubic meter.

B. Subsequent to the establishment of an acceptable analytical procedure for measuring hexavalent chromium in the ambient air:

1. The maximum 24-hour hexavalent chromium at any location shall not exceed the Minimum Detection Limit (MDL) of that procedure or a value of 1.0 nanogram per cubic meter whichever is greater.

>

Code of Maine Rules

06-096 Department of Environmental Protection, Bureau of Water Quality Control

Chapter 543 Rules to Control the Subsurface Discharge of Pollutants by Well Injection

>

1. Definitions

As used in these rules, the following terms have the following meanings. Other terms used in these rules have the meanings set forth at 38 M.R.S.A., §361-A.

A. Aquifer means a geologic formation, group of formations, or part of a formation composed of rock or sand and gravel that stores and transmits significant quantities of recoverable water, as identified (or subsequently confirmed) by the Maine Geological Survey.

B. Board means the Maine Board of Environmental Protection.

C. Fluid means any material or substance which is capable of movement, whether in a semisolid, liquid, sludge, gas or other physical state.

D. Formation means a body of rock or sand and gravel characterized by a degree of lithologic homogeneity that is mappable on the earth's surface or traceable in the subsurface.

E. Total Dissolved Solids means total dissolved (filterable) solids as determined by standard test method 92 in "Standard Methods for the Examination of Water and Wastewater," 14th edition, 1976, which is "Glass Fiber Filtration at 180 °C."

F. Underground Source of Drinking Water (USDW) means any aquifer, except those aquifers exempted in accordance with section 5 of these regulations.

G. Well means a bored, drilled or driven shaft or a dug hole, which has a depth greater than its largest surface dimension.

>

2. Classification of Wells

A. Class I. Wells used to discharge hazardous waste or any fluids beneath the lowermost formation containing an underground source of drinking water, except those wells that fall within the definition of a Class II or III well.

B. Class II. Wells used to discharge fluids:

1. Which are brought to the surface in connection with conventional oil or natural gas production and may be commingled with wastewaters from gas plants which are an integral part of production operations, unless those fluids are classified as hazardous waste at the time of their discharge; or

2. for enhanced recovery of oil or natural gas; or

3. for storage of hydrocarbons which are liquid at standard temperature and pressure.

C. Class III. Wells used to discharge fluids for extraction of minerals, including:

1. Mining of sulfur by the Frasch process;

2. in situ production of uranium or other metals. This category (C)(2) includes only in situ production from ore bodies which have not been conventionally mined. Solution mining of conventional mines, such as stopes leaching, is included in Class V.

3. solution mining of salts or potash.

D. Class IV. Wells used to discharge hazardous waste into or above an aquifer, whether or not the aquifer is an underground source of drinking water.

E. Class V. Wells not included in Classes I, II, III or IV.

>

3. Prohibited Discharges.

A. General. All subsurface discharges of fluids into or through a well are prohibited except as authorized in accordance with these rules.

B. Hazardous Wastes. The subsurface discharge of hazardous waste into or through a Class IV well is expressly prohibited. For the purposes of these rules, "hazardous wastes" are those substances identified as hazardous by the Board in Regulations, chapter 850, section 3(C). This prohibition is established pursuant to the authority conferred upon the Board by Title 38, M.R.S.A., §420(2), and is subject to the following limited exception.

A Class IV well being used to discharge hazardous waste on the date these rules are officially proposed may continue to be used for such a discharge for a period of no more than six months after the effective date of these rules, provided that during that time there is no increase in the amount, or change in the type, of hazardous waste discharged, compared to that previously discharged.

C. Radioactive Waste. The subsurface discharge of radioactive waste into or through a Class IV well is expressly prohibited. Any discharge of radiological warfare agents or high level radioactive waste to the waters of the State, directly or indirectly, is expressly prohibited by Title 38 M.R.S.A., §420(3). Any other waste that contains radioactivity, regardless of amount or concentration, is declared to be a toxic or hazardous substance pursuant to Title 38 M.R.S.A., §420(2), based upon the criteria stated therein, and its discharge to the groundwater is prohibited.

D. Preservation of Drinking Water Quality. Any subsurface discharge into or through a Class V well that would cause or allow the movement of fluid into an underground source of drinking water that may result in a violation of any Maine Primary Drinking Water Standard, or which may otherwise adversely affect human health, is prohibited.

>

4. Permitted Discharges.

A. Class I, II and III wells. Discharges of fluids into or through Class I, II, or III wells may be maintained, provided that those requirements applicable to State programs in the regulations adopted by the U.S. Environmental Protection Agency pursuant to the Federal Safe Drinking Water Act on or before April 1, 1983 are satisfied. These regulations are found in Title 40 of the Code of Federal Regulations, Parts 144, 145, 124 (insofar as they are made applicable to State programs by 40 CFR §145.11) and 146. For purposes of this subsection 4(a), the terms "Director" and "State Director" shall mean the Maine Board of Environmental Protection or its delegated representative.

B. Class V Wells. Discharges of fluids into or through Class V wells may be maintained, provided that (1) a waste discharge license therefor is issued by the Board prior to commencement of the discharge (or it is determined by the Board that the proposed discharge is beyond the Board's waste discharge licensing jurisdiction), and (2) any other applicable statutes and regulations administered by the Board are satisfied, including the requirements of section 3(D) of these regulations.

>

5. Exemption of Certain Receiving Waters

After notice and opportunity for a public hearing, and subject to the approval of the U.S. Environmental Protection Agency, an aquifer or a portion thereof may be exempted form being an underground source of drinking water when the Board identifies the location of the aquifer or portion in clear and definite terms, and finds that it meets each of the following three criteria:

A. The groundwater contained in the aquifer or its portion has been classified GW-B by the Maine legislature in accordance with Title 38 M.R.S.A., §371-B;

B. It is not being used as a public source of drinking water; and

C. It will not in the future serve as a public source of drinking water because:

1. It is so contaminated or so situated that it would be economically or technically impractical to recover the water or render it fit for human consumption; or

2. It is mineral, hydrocarbon or geothermal energy producing, or has been demonstrated by a license applicant as part of a license application for a Class II or III well operation to contain minerals or hydrocarbons that are expected to be commercially producible, considering their quantity and location.

EXHIBIT 5.5-2

URS Consultants, Inc.
CALCULATION COVER SHEET

Client: LORING AFB Project: OPERABLE UNIT OU 8

Project/Calculation Number:

Title: PROCESS BUILDING DESIGN.

Total number of pages (including cover sheet):

Total number of computer runs: NONE

Originator: P. PAL Date: 12/7/94

Checker: ANDREAS PARASCHOS / ALDONA ULANECKA ~~[illegible]~~ Date: DEC 13, 1994

Description and Purpose: DESIGN OF PROCESS BUILDING INCLUDING FOUNDATION,

Design bases/references/assumptions: INCLUDED WITH THE CALCULATION

Remarks/conclusions:

1. CRITERIA AND COMPUTATIONS WERE WELL ORGANIZED AND WELL DONE.
2. ADD CROSS BRACING MEMBERS AT ROOF FRAME IN TWO PLACES FOR TRANSFERING OF WIND LOAD TO THE BRACED COLUMNS.
3. USE $\frac{1}{4}$" MINIMUM FILLET WELD AT $\frac{3}{4}$" BASE METAL PER AWS AND AISC
4. USE 12" MAXIMUM TIE SPACING FOR CONCRETE COLUMN WHEN #6 BARS ARE USED AS MAIN REBAR PER ACI.

Revision No.	Description of Revision	Approved by/date

Project Manager

URS CONSULTANTS, INC.

PAGE 1 OF
SHEET NO. OF
JOB NO.
MADE BY P.P. DATE 11/14/94
CHKD. BY DATE

PROJECT LORING AIRFORCE BASE
SUBJECT PROCESS BUILDING – LORING FT-4

REF. PAGE

Steel frame building including foundation

1. Approximate building size 20'-0(W) x 50ft-(L)
2. Minimum clear height from the floor = 18'-0.
3. Building will have insulated metal roof and insulated sandwitch panel siding. Rigid insulation be used for roof and wall.
4. The building will have two insulated man door 3'-0 x 7'-0 and one roll up door 10'-0(W) x 10'-0H
5. The building will be designed as braced building in both direction.
6. All steel for framing member including girts shall be of ASTM A-36 steel. No cold form steel shall be used except for doorframe.
7. All concrete used for foundation and floor slab shall be equivalent to f'c = 4000psi air entrained.

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MADE BY PP DATE 12/10/94
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PROJECT LORING AIRFORCE BASE
SUBJECT FIRE TRAINING SITE
PROCESS BUILDING

REF. PAGE

The building was originally designed to have 17'-6" clear height. At that time the equipment sizes were not selected to finalize minimum clear height required for the equipments to be used. After the selection of equipment had been finalized it was found the building is too high. Therefore the height of the building has been redued by 3'-0. The previous Calction has not been revised because it will give a building with higher saftey factor. Therefore all architectural and steel drawings are modified to reflect the change in height.

URS CONSULTANTS, INC.

PROJECT Loring Airforce Base
SUBJECT Loring FT-4
PROCESS BUILDING

SHEET NO. OF
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REF. PAGE

Design Loads for the Building

1. Design shall be in accordance with the latest edition of BOCA, ANSI A58.1, ACI 318 and American Institute of steel construction Manual.

2. LOADS TO BE CONSIDERED

a) Wind velocity = 80 mph.
(Caribou /

b) Ground snowload = 68 lbs/sft

c) Earthquake zone - 1

d) Frost Depth - varies between 70" — 80"
For caribou area Use 6'-6'

e) Treatment Building
Roof live load = 50 lbs/sft

f) Auxiliary load = 10 lbs/sft

g) Purlins and rafters shall be designed for a point load of 1000 lbs at midspan in addition to uniformly distributed Live or snow and auxiliary load but the effect will not be included in the design of rafter and columns.

URS CONSULTANTS, INC.

PROJECT Loring Airforce Base	PAGE 3 OF
SUBJECT Loring FT-4	SHEET NO. OF
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REF. PAGE

h) Allowable bearing pressure is used in the design. $-4^k/ft^2$ for undisturbed Till

i) Floor slab at grade - 500 lbs/sft

Equipment loading - Actual load.

3. For structural steel and Reinforced Concrete design allowable stress design was used. The main loading on the building is wind and snow.

Flat roof snow load

$$p_f = 0.7\, C_e\, C_t\, I\, p_g.$$

$C_e = 0.8$ roof exposed on all side

$C_t = 1.0$ Heated structure.

$I = 1.0$

p_g = ground snow load = 68 lbs/sft

Design roof snow load = $.7 \times .8 \times 1 \times 1 \times 68$
= 38.08 lbs/ft².

Roof live load = 50 lbs/ft².

Auxiliary live load = 10 lbs./ft².

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PROJECT Loring Airforce Base

SUBJECT Loring F.T.4 - Process Building
Roof Design

REF. PAGE

Roof Design.

Roof Deck.

Design Load = $\overset{LL}{50} + \overset{AL}{10}$ = 60 lbs/sft

Roof sandwich Panel roof. - standing Seam.

Liner plate ontop assume 22g = 1.8 lbs/ft²

Bottom deck $1\frac{1}{2}''$ deep 20g = 2.2 lbs/ft²

Rigid insulation 2" thick = 3.0

Total Dead wt = 7.0 lbs/ft².

Load on roof = 60 + 7 = 67 lbs/ft²

22g deck $1\frac{1}{2}''$ deep 5'-0 span continuous over 3 span will carry uniform load of 138 lbs/sft.

Design of Purlin

Purlin P-1 span of purlin = 16'-8"

Calculation of Load on purlin.

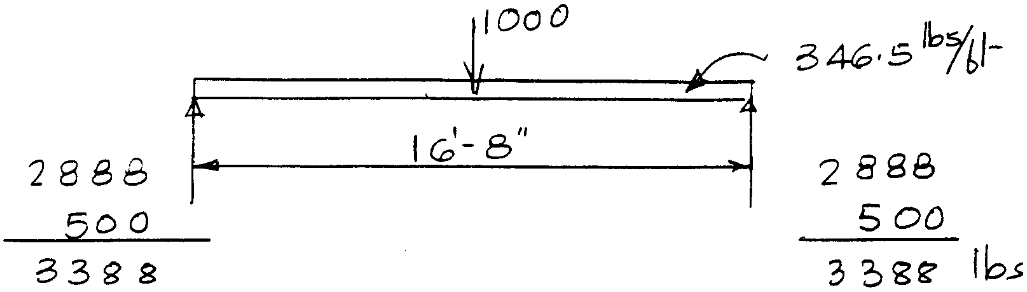
Udl LL+AL	= 5 × 60	=	300 lbs/ft
DL roof	= 7 × 5	=	35 lbs/ft
self wt	=		11.5.
			346.5 lbs/ft

Conc. Load 1 kips at Center span.

PROJECT Loring Airforce Base

SUBJECT Loring FT-4 - Process Building Roof Design.

REF. PAGE



$$\text{Mom at Midspan} = \frac{1000 \times 16.67}{4} + \frac{346.5 \times 16.67^2}{8}$$

$$= 4167.5 + 12036.06 = 16203.56 \text{ lbft}$$

Lighter weight member could have been used. because of connection of pipesupport, heaters etc W8X18 is used

Try with W8X13 $S = 9.91 \text{ in}^3$

$$f_b = \frac{16203.56 \times 12}{9.91} = 19621 \text{ psi}$$

with W8X18 $S_x = 15.2 \text{ in}^3$

$$f_b = \frac{16203.56 \times 12}{15.2} = 12793 \text{ psi}$$

Use W8X18.

Axial force on purlin from wind analysis page 15

$r_y = 1.23$ $P = 7.25^k$ $(\pm)$

$A = 5.26 \text{ in}^2$ $f_a = \frac{7.25}{5.26} = 1.38$ ksi

Since the top flg braced $F_a = 21.6$ $F_b = 22$ ksi.

$$f_a/F_a + \frac{f_b}{F_b} = \frac{1.38}{21.6} + \frac{12.79}{22} = .064 + .58 = .644 < 1.33$$

Use W8X18.

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Purlin P-2

$b = 2.5 + 1.5 = 4'0.$

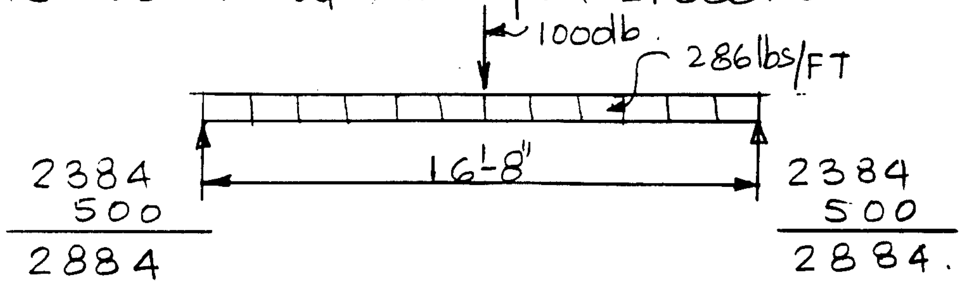
Udl = LL + AL = 4 × 60 = 240 lbs/ft

DL of roof = 4 × 7 = 28

Self wt (W8X18) = 18

286

Conc load at mid span = 1000 lbs.



$$\text{Max}^{m} \text{ Mom} = \frac{1000 \times 16.67}{4} + \frac{286 \times 16.67^2}{8}$$

$$= 4167.5 + 9934.53 = 14{,}102 \text{ lb ft}$$

Use W 8X18 $S = 15.2 \text{ in}^3$

$f_b = 14102 \times 12 / 15.2 = 11133$ psi ok.

Axial force from wind analysis = 7.25^k (±) page 15

$A = 5.26 \text{ in}^2$ $r_y = 1.23$ top flg is braced.

$f_a = 7.25/5.26 = 1.38$ Ksi $F_a = 21.6$ & $F_b = 22$

$$f_a/F_a + f_b/F_b = \frac{1.38}{21.6} + \frac{11.133}{22} = .064 + .506 = .57 < 1.3$$

Member used W8X18 Satisfactory.

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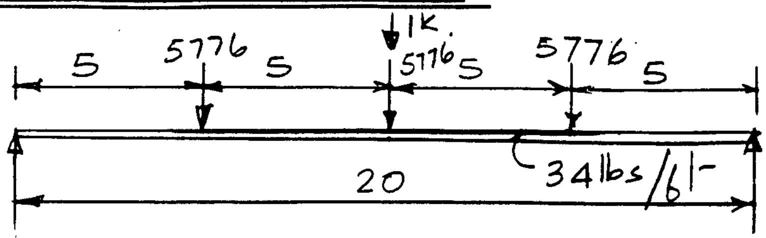
REF. PAGE

Rafter on line 2 and 3



340

340
5776
2888
9004
500
9504 lbs

Load from purlin P_1 = DL + LL = 2888 + 2888
= 5776 lbs.

selfwt of beam   Say 34 lbs/ft

Maximum Mom = $9504 \times 10 - 5776 \times 5 - \frac{34 \times 10^2}{2}$

$= 95040 - 28880 - 1700 = 64460$ lb ft

Try with W 14 X 30 $S_x = 42 \ in^3$

$L_u = 8.7$

$f_b = \frac{64460 \times 12}{42} = 18.417$ psi

Use W14X30 as rafter

Axial force on the member due to wind is negligible.

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PROJECT Loring Airforce Base
SUBJECT Loring F.T.-4 Process Building
Roof Design

REF. PAGE

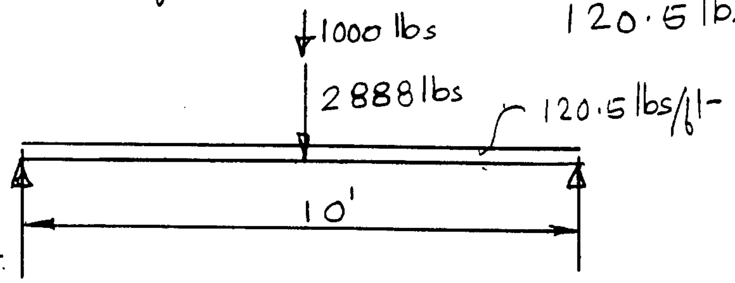
Beams on Line ① & ④

Assume 1'-6" overhang will be acting on the beam.

$$\text{Udl} = 1.5 \times 67 = 100.5 \text{ lbs/ft}$$

$$\text{Selfwt} = \underline{20 \text{ lbs/ft}}$$

$$120.5 \text{ lbs/ft}$$



1444
$\underline{602.5}$
2046.5
$\underline{500}$
25465 lbs.

$$M = 2546.5 \times 5 - \frac{120.5}{2} \times 5^2$$

$$= 12732.5 - 1506.25 = 11226.25 \text{ k ft}$$

Use W8x18 $\quad S_x = 15.2 \text{ in}^3$.

$$f_b = \frac{11266.25 \times 12}{15.2} = 8862.83 \text{ lbs/in}^2$$

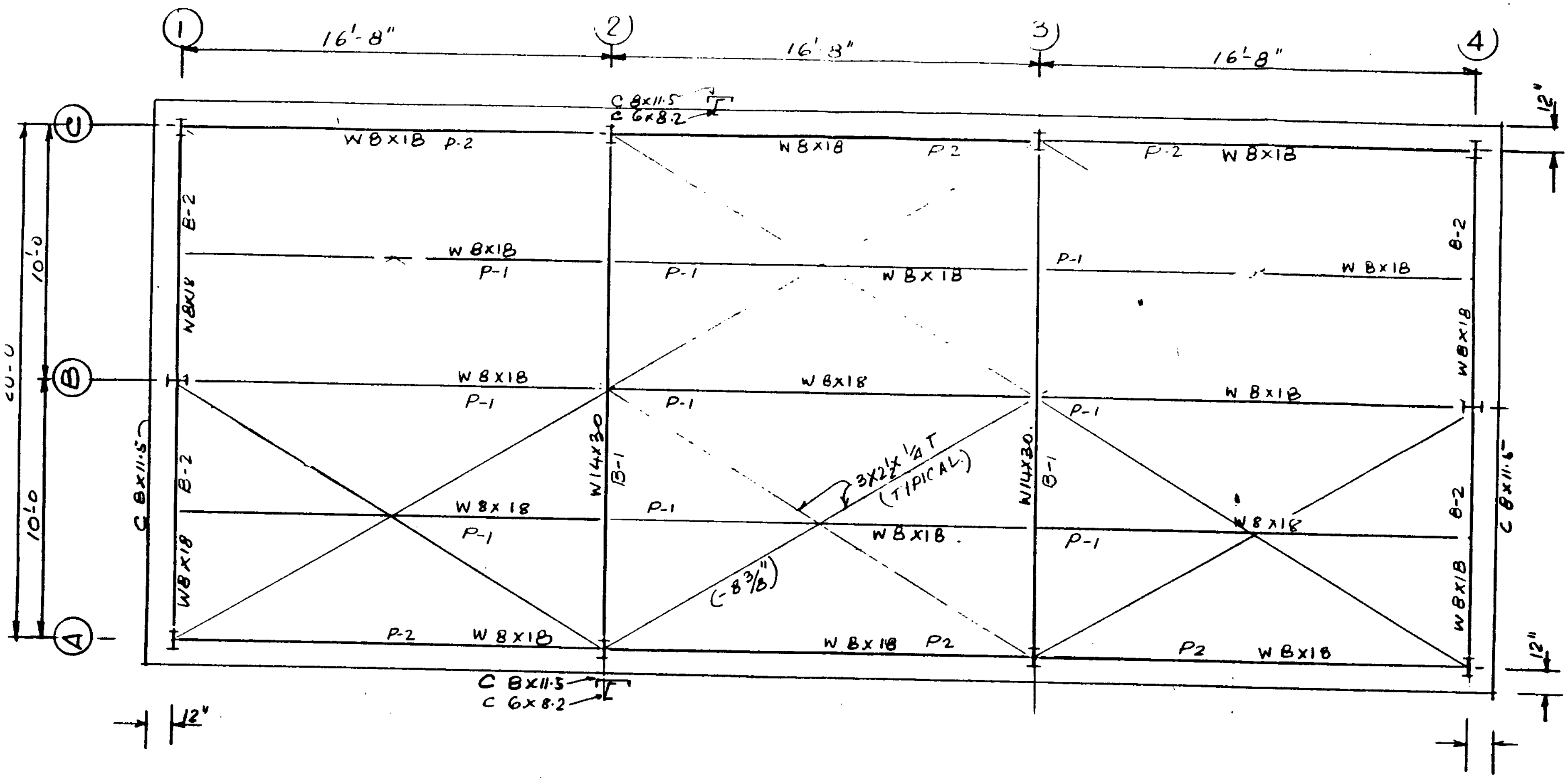
Use W8x18

Axial force due to wind. = 4.86k Page 16.

Top flg is braced. Axial stress due to wind

Member used W8x18 is small $f_a = \frac{4.86}{5.26} = .924 \text{ksi}$
$A = 5.26 \text{ in}^2$

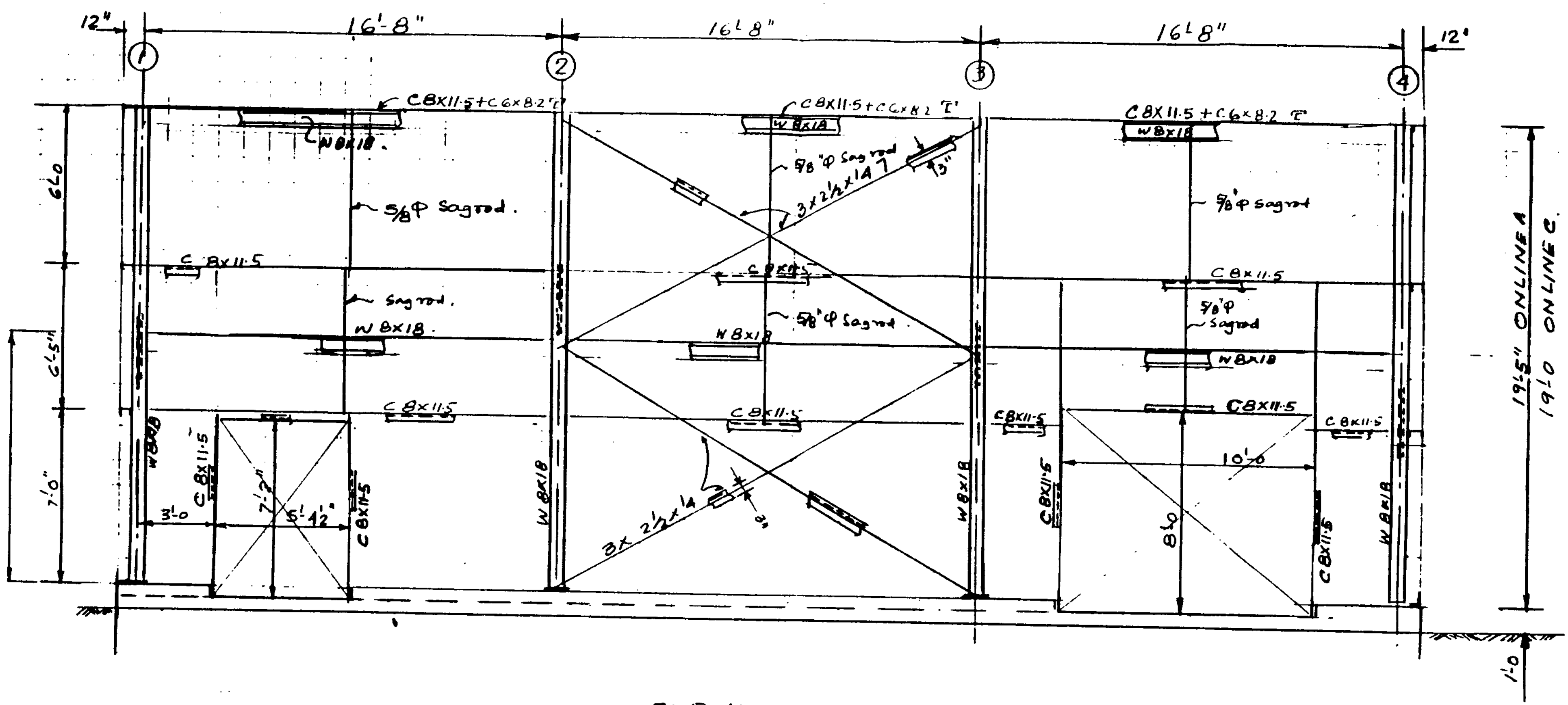
Member used ok by inspection.



ROOF PLAN

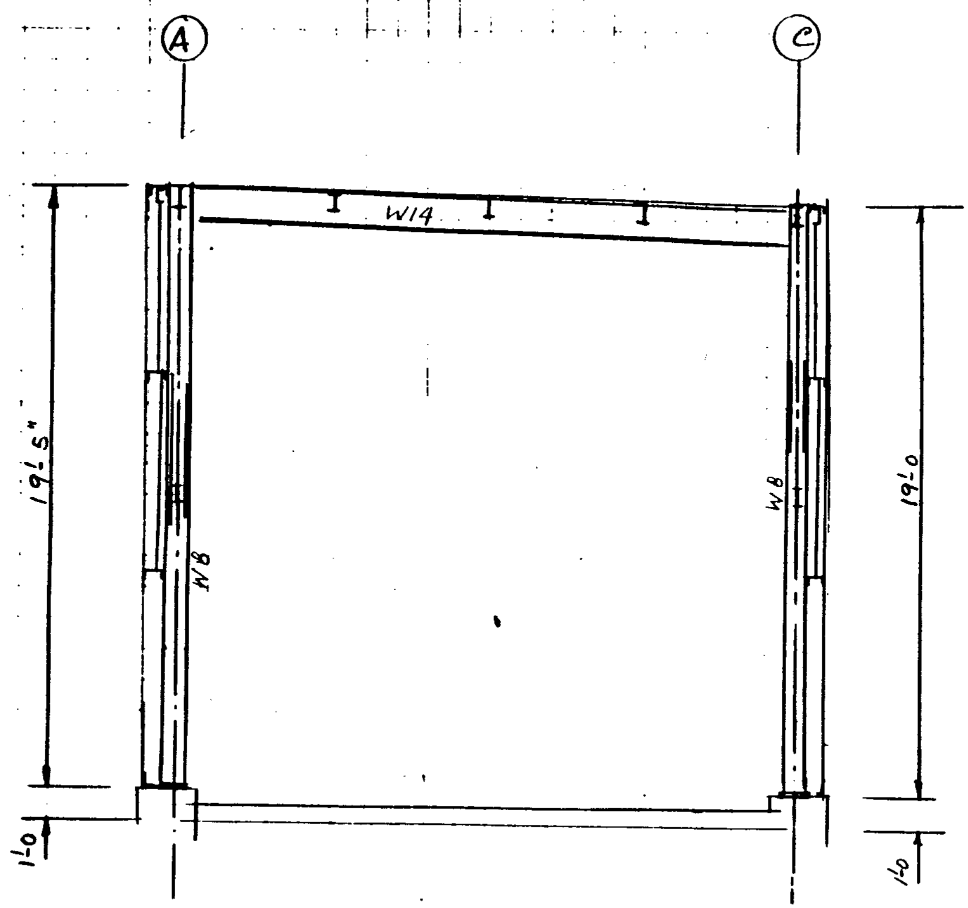
SCALE 1/4" = 1'-0

ROOF DECK 1½" DEEP 22G

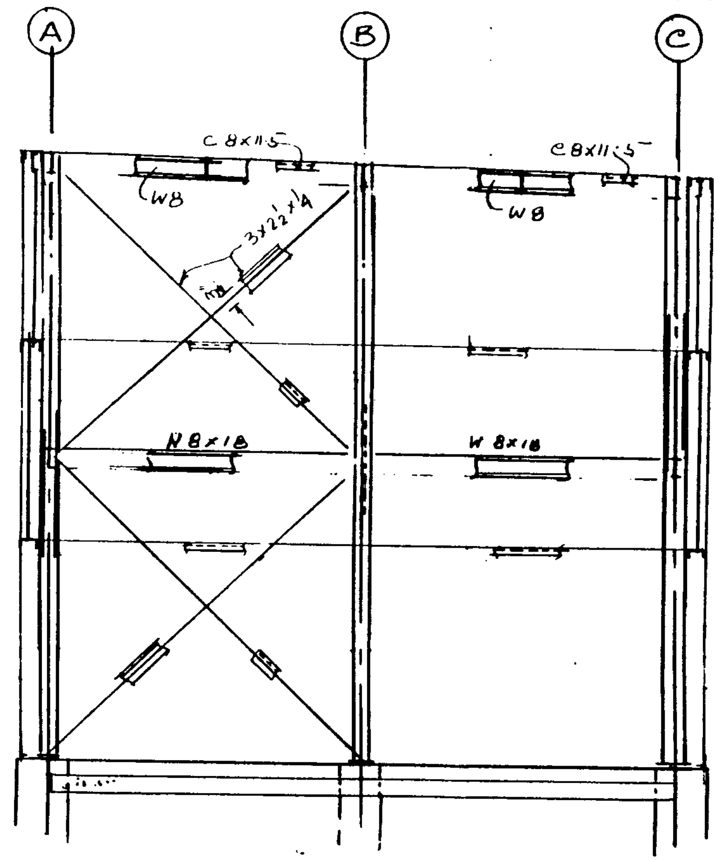


ELEVATION ON LINE A.

ELEVATION ON LINE C
SIMILAR, NO OPENING IN WALL.



SECTIONAL ELEVATION
INTERIOR BAY.



SECTIONAL ELEVATION ON LINE-1
LOOKING TOWARD LINE 1 FROM INSIDE.

(SECTIONAL ELEVATION ON LINE-4
OPPOSITE HAND)

REF. PAGE

Windforce Calculation — ANSI A-58.1-1982

Wind velocity = 80mph.

$q_z = .00256\ k_z (IV)^2 = .00256 \times .87 (1 \times 80^2)$
$= 14.25$ psf.

$I = 1.0$

$k_z = .87$

Exposure C

Height of building 20' above ground level.

Gust response factor = 1.29

design $q = 1.29 \times 14.25 = 18.39$ Say 18.5 lbs/sft-

Wall pressure

Windward side = $C_p = 0.8$.

Leeward side. L/B 0-1 $C_p = -.5$

Roof Pressure coefficient $= -.7$
$h/L \approx 1.0$ $\theta \approx 0°$

uplift pressure on roof = $.7 \times 18.5$
$= 12.95$ psf.

Design pressure on the windward side
$= .8 \times 18.5 = 14.8$ lbs/ft²

Design pressure on the leeward side = $.5 \times 18.5 = 9.25$ lbs/ft²

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PROJECT: Loring Air force Base
SUBJECT: Loring FT-4 Procarp building
Wind force Calculation

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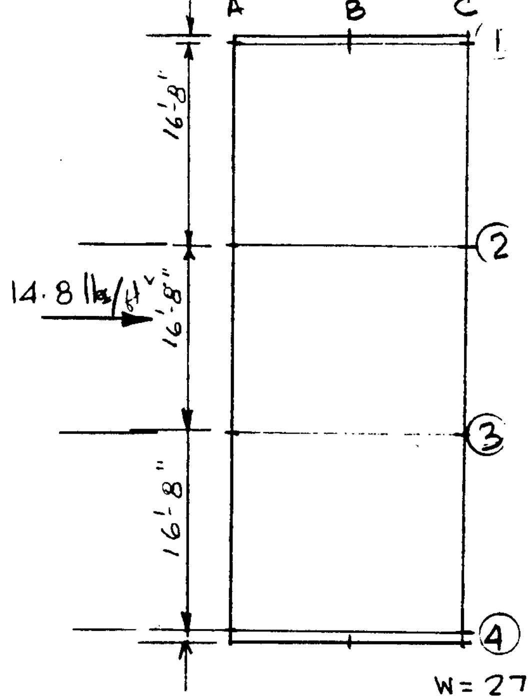
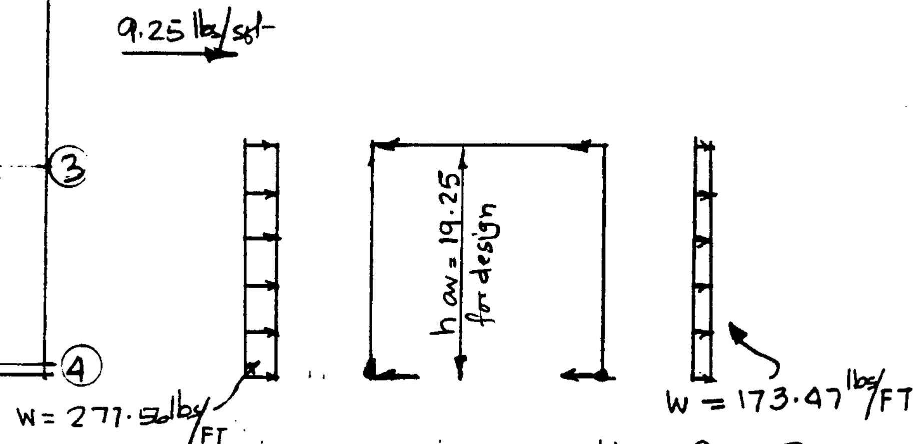
Wind Normal to the length of the building

Assume Girt will be Continuous.





Frame online ② or ③

WIND WARD SIDE.

Total wind force on Windward side/ft

$$W = .5 \times 16.67 \times 14.8 + .625 \times 16.67 \times 14.8$$
$$= 123.36 + 154.20 = 277.56 \text{ lbs/FT}$$

Reaction at the bottom $= \frac{.278 \times 19.25}{2} = 2.68^k$.

" " " " top $= 2.68^k$.

LEEWARD SIDE

Total wind force on Leeward Side $= .5 \times 16.67 \times 9.25 +$
$.625 \times 16.67 \times 9.25$
$= 77.10 + 96.37 = 173.47$ lbs/ft

reaction at top $= .174 \times 19.25/2 = 1.67^k$.

reaction at bottom $= 1.67^k$

PROJECT Loring Airforce Base
SUBJECT Loring F.T. 4 – Process Building
Wind force Calculation

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Calculation of Wind force on Col line ① and 4

effective width of the surface to resist the wind force

$$b = .375 \times 16.67 + 1.25 = 7.5$$

Wind force / ft on windward side = $7.5 \times 14.8 = 111$ lbs/ft

Reaction at the top $= .111 \times \frac{9.25}{2} = .51^k$

Reaction at the brace pt $= .111 \times 9.25/2 + .111 \times 10/2 = .51 + .56 = 1.0$

Reaction at the bottom $= .56^k$.

Wind force per ft on leeward side $= 7.5 \times 9.25 = 69.38$ lbs/ft

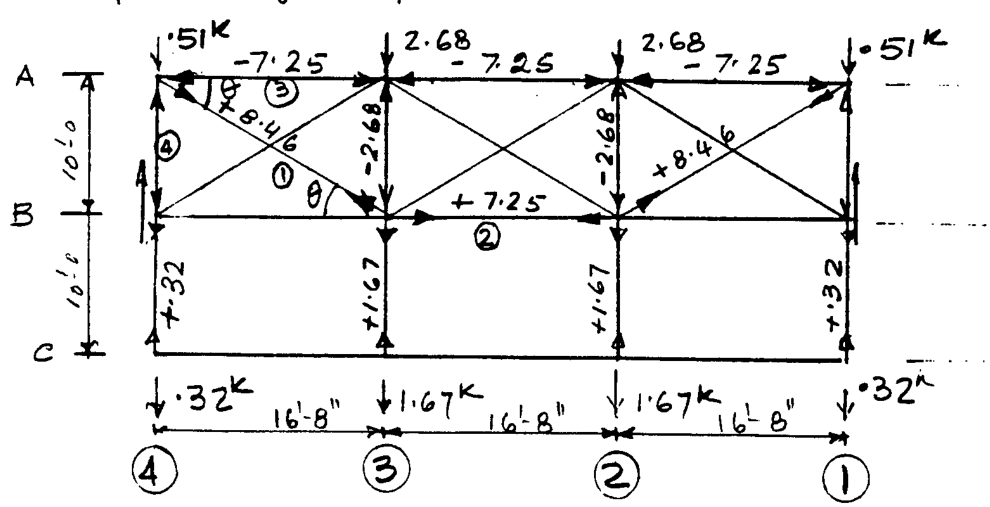
Reaction at the top $= .06938 \times \frac{9.25}{2} = .32^k$

Reaction at the brace pt $= .32 + .06938 \times 10/2 = .67^k$

Reaction at the bottom $= .06938 \times 10/2 = .35^k$

Wind pressure on the side wall $= .7 \times 18.5 = 12.95$ lbs/ft²

Analysis of roof bracing



Roof Plan.

Reaction on line ① and 4 $= 0.51+2.68+1.67+0.32$
$= 5.18^k$.

$l_{dia} = \sqrt{10^2+16.67^2} = \sqrt{377.89} = 19.44$

Force on Member ① :
(See page 15)

$M_① \sin\theta = 2.68+1.67 = 4.35$

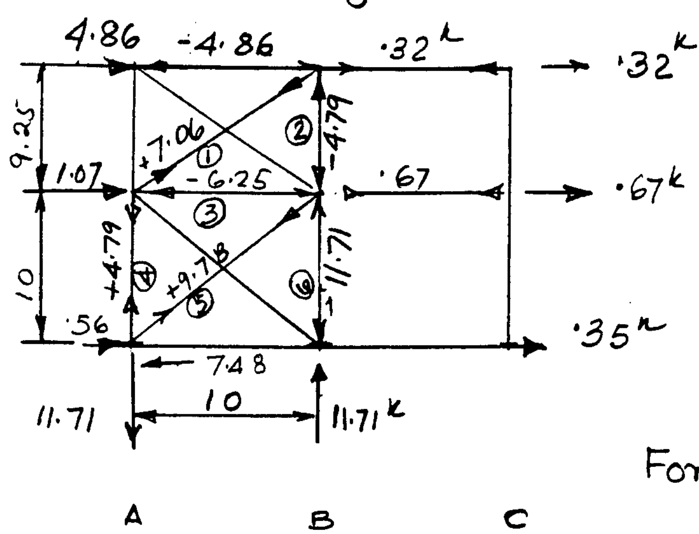
$M_1 = \frac{4.35 \times 19.44}{10} = 8.46^k$ (Tension)

Force in M_2 $\quad M_2 = 8.46 \cos\theta = \frac{8.46 \times 16.67}{19.44}$
$= 7.25^k$ (Tension)

Force in M_3 $\quad M_3 = 8.46 \cos\theta = \frac{8.46 \times 16.67}{19.44}$
$= 7.25^k$ Compression.

Force in M_4
$= 4.35 + .51 = 4.86^k$ (compression)

Vertical Bracing analysis on line ① and ④



ELEVATION LINE ① or ④

Diagonal length
$L_1 = \sqrt{10^2 + 9.25^2} = 13.62$

$L_2 = \sqrt{10^2 + 10^2} = 14.14$

Force in 1 $= \frac{5.18 \times 13.62}{10}$
$= 7.06^k$ (T)

Force in member 2 $= 7.06 \times 9.25 / 13.62$
$= 4.79^k$ (C)

Force in member 3 = $5.18 + 1.07 = 6.25^k$ (C)

Force in Member 4 = $7.06 \times 9.25 / 13.62 = 4.79$ (T)

Force in Member 5 = $\frac{6.92 \times 14.14}{10} = 9.78^k$ (T)

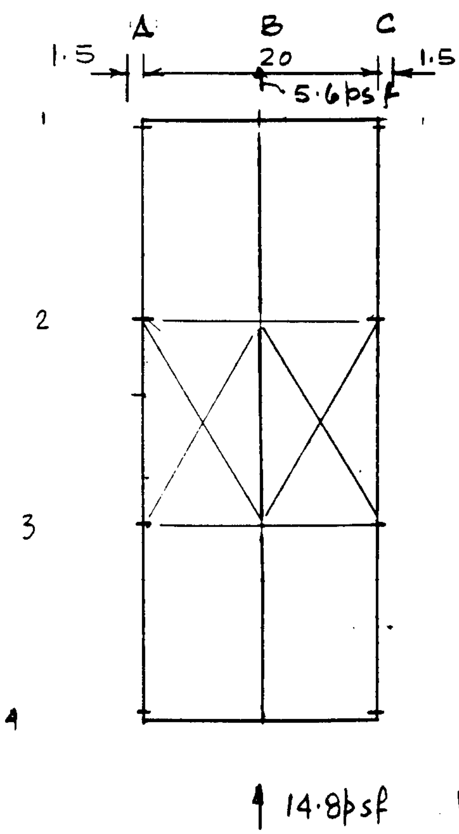
Force in Member 6 = $4.79 + \frac{9.78 \times 10}{14.14} = 4.79 + 6.92$

$= -11.71^k$

Reaction at A-4 or A-1 = 11.71^k (T) Vertical

Horizontal = $6.92 + .56 = 7.48^k$.

Wind Force analysis when Wind is perpendicular to 20'-0 side



Wind force on windward side

$= .8 \times 18.5 = 14.8$ lbs

Wind force on the leeward side

$B/L = 2.5$ Cp = .275 use .3

Wind force on Leeward side = $.3 \times 18.5$

$= 5.55$ lbs/ft²

say 5.6

Wind force on B-1 at top h = 19.25

Windward side = $14.8 \times 20 \times .625 \times 19.25/2$

at col B1 (Top & Bottom) = 1780.6 lbs

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WIND FORCE CALCULATION

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Windward side at Col A1 and C1 at top.

$b = .375 \times 10 + 1.5$
$= 5.25$

Wind force $= \frac{9.25}{2} \times 5.25 \times 14.8 = 359.36$ lbs

At braced point 10 from bottom $= 9.63 \times 5.25 \times 14.8$
$= 747.86$ lbs

$h = \left(\frac{9.25 + 10}{2}\right) = 9.63$ and $b = 5.25$

Wind force at the base $= 5 \times 5.25 \times 14.8 = 388.5$ lbs

Leeward side.

Wind force on B-4 at top and bott $h = 19.25$

leeward side at Col B-4 (Top & bott) $= 5.6 \times 20 \times .625 \times \frac{19.25}{2}$
$= 674$ lbs

Leeward side wind force on A4 or C4 at the top.

$b = 5.25$

Wind force at top. $= 5.6 \times 5.25 \times 9.25/2 = 136$ lbs.

Wind force on A-4 or C4 at the brace point

$= 5.6 \times 5.25 \times 9.63 = 283$ lbs

Wind for on A-4 or C-4 at the base $= 5.6 \times 5 \times 5.25$
$= 147.0$ lbs.

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Wind Analysis in Longitudinal Direction

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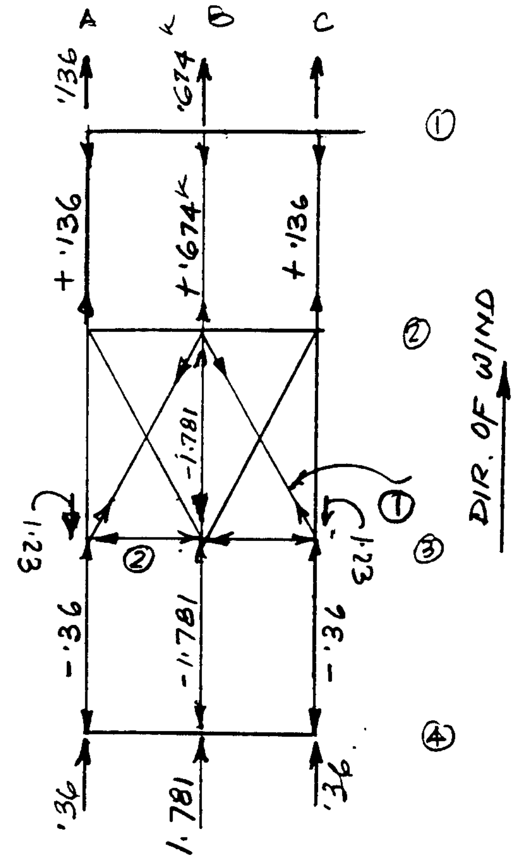
Wind analysis AT ROOF LEVEL

At roof level.



$l_1 = \sqrt{10^2 + 16.67^2}$

$= 19.44$

Force in Member ①

$= \left(\frac{1.781 + .674}{2}\right) \times \frac{19.44}{16.67}$

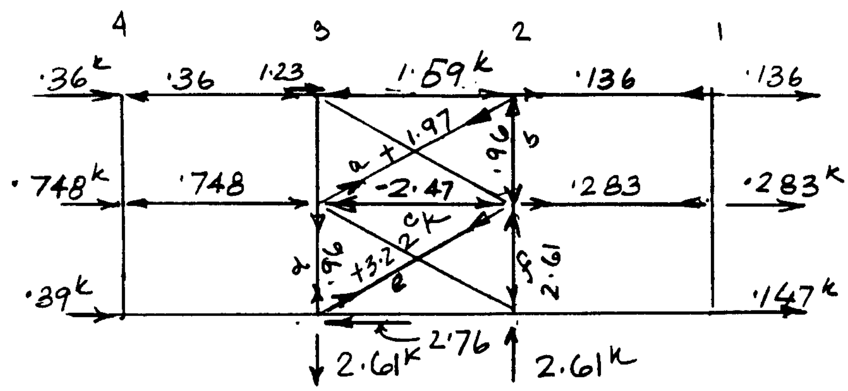
$= 1.23 \times \frac{19.44}{16.67} = 1.43^k \,(T)$

FORCE IN MEMBER ②

$F = \frac{1.43 \times 10}{19.44}$

$= .74^k \,(C)$

VERTICAL BRACING ANALYSIS ON LINE A or C



$l_{1\,diag} = \sqrt{16.67^2 + 9.28^2}$

$= 19.06$

$l_{2\,diag} = \sqrt{16.67^2 + 10^2}$

$= 19.44$

LINE C SHOWN.

LONGITUDINAL WIND ANALYSIS ON LINE A OR C

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PROJECT Loring Air Force Base
SUBJECT F.T-4 Process BUILDING
WIND ANALYSIS IN Longitudinal Dir.

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Force in a $= \frac{(1.59 + .136) \times 19.06}{16.67} = 1.97^k$ (T.)

Force in b $= 1.97 \times 9.25/19.06 = .96^k$ (C)

Force in Member C $= 1.73 + .748 = 2.47^k$ (C)

Force in member d $= .96^k$ (T)

Force in member e $= \frac{(2.47 + .283) \times 19.44}{16.67} = 3.22^k$ (T)

Force in member f $= .96 + \frac{3.22 \times 10}{19.44} = .96 + 1.65 = 2.61^k$

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Wind Analysis

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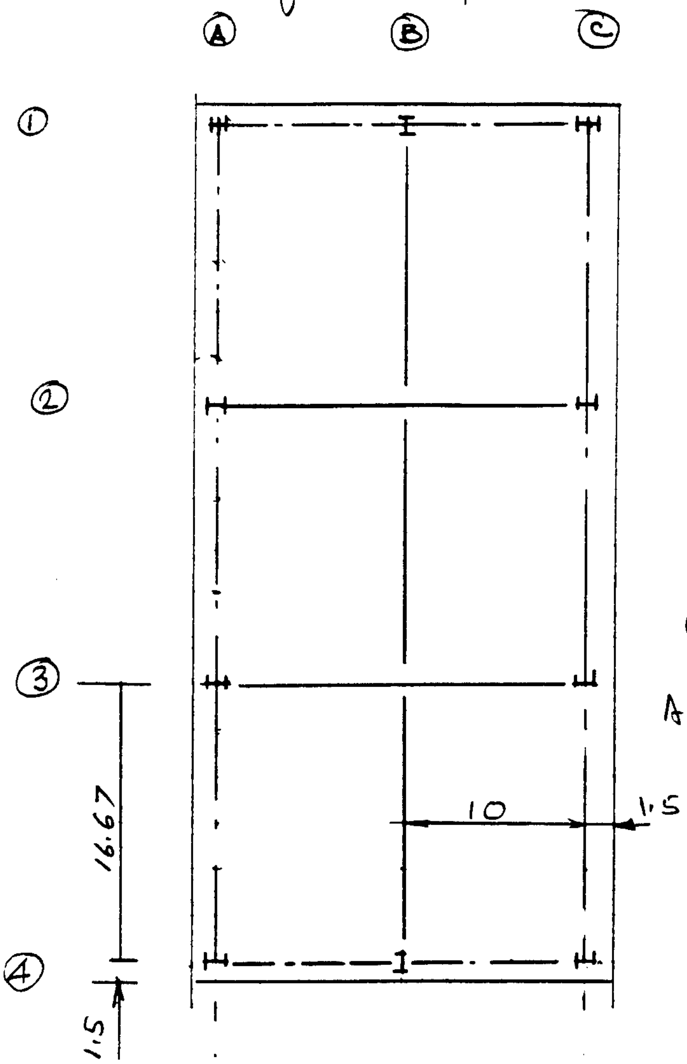
Calculation of wind force at the roof



uplift force at roof due to wind = $.7 \times 18.5$
$= 12.95$ say 13 psf.

uplift force at A_3, C_3 A_2 and C_2
$= 16.67 \times 11.5 \times 13 = 2492$ lbs.

uplift force at A_4, A_1 and C_1, $C_4 = 9.835 \times 6.5 \times 13$
$= 831$ lbs

uplift on B-4 and at B-1 $= 10 \times 9.835 \times 13$
$= 1279$ lbs

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Design of Girt.

Basic Wind force = 18.5 lbs/ft²

$p = q_h(G c_p - G c_{pi})$

A = 40×19.5 = 780 sft

$= q_h(1 + .25) = 18.5 \times 1.25$

$G c_p = 1.0$
$G c_{pi} = .25$

$= 23.13$ psf

Girt spacing use 7'-0 for design purpose.

Try with C 8×11.5 $S_x = 8.14$

Wind load = 23.13 × 7 = 161.91 lbs/ft.

siding consists of 26ga Liner panel = 1.5

2" rigid insulation = 3 lbs/sft

Outer panel 24ga = 2.0
6.5 lbs/sft

Wt of the girt C 8×11.5

Total vertical load/ft = 7×6.5+11.5
= 57 lbs/ft

Wind horizontal load = 7×23.13 = 161.91 say 162 lbs/ft.

$M_x = 162 \times 16.67^2/8 = 5627.25$ lbft

$M_y = 57 \times 16.67^2/8 = 1980$ lbft

Try with C 8X11.5 $\qquad S_x = 8.14 \text{ in}^3$

$S_y = .781 \text{ in}^3$

$$f_{bx} = \frac{5627 \times 12}{8.14} = 8295.33 \text{ psi}$$

$$f_{by} = \frac{1980 \times 12}{.781/2} = 60845$$

use 1/2 value of sy. because the sheeting is connected only at the flange. To reduce the vertical stress use one sag rod at the center

Mom at the center due to vert. load

$$M = \frac{57 \times 8.335^2}{8} = 495 \text{ lb ft}$$

$$f_{by} = \frac{495 \times 12}{.781/2} = 15210 \text{ psi}$$

$$f_{bx} + f_{by} = 8295 + 15210 = 23505 \text{ psi} \quad ok$$

Use C 8X11.5 as a girt with a sag rod at center along line A and C.

REF. PAGE

On line 1 and 4

Wind force acting on the girt = 23.13 psf

Try with C 8x11.5

$S_x = 8.14 \text{ in}^3$

Wind force/ft = 7x 23.13 = 162 lbs/ft $S_y = .781 \text{ in}^3$.

$M_x = 162 \times 10^2/8 = 2025$ lbft

Vertical load/ft = 7 x 6.5 + 11.5 = 57 lbs/ft

$M_y = 57 \times 10^2/8 = 712.5$ lbft

$f_y = \dfrac{712.5 \times 12}{.781/2} = 21895$ psi

$f_x = \dfrac{2025 \times 12}{8.41} = 2889$ psi

$f_x + f_y = 2889 + 21895 = 24784 < 1.33 \times 22000 = 29260$ p.

Use C 8x11.5 as a girt without any sag rod.

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SUBJECT FT-4 - Process Build.
Design of Eave Girt

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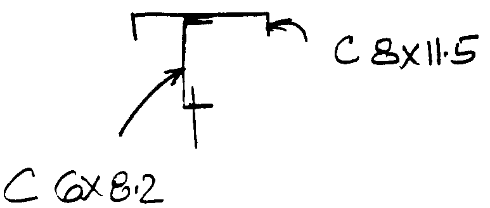
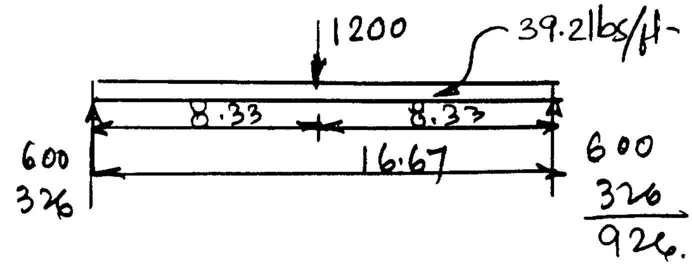
Design of Eave Girt on line A & C.

Force on the sag rod $= 1.1 \times 6.5 \times 16.43 \times 8.33 + 1.1 \times 8.33$
$= 978.56 + 210.75$ (2×11.5)
$= 1189.31$ lbs.





$Udl = 3 \times 6.5 = 19.5$

member $= \frac{19.7}{39.2 \text{ lbs/ft.}}$

$M_x = 1.2 \times \frac{16.67}{4} + \frac{.0392 \times 16.67^2}{8} = 5 + 1.36 = 6.36.$

Properties of the combined section

$S_{x_1} = 5.3 \text{ in}^3$ $S_{x_2} = 14.5 \text{ in}^3$

$S_y = 8.3 \text{ in}^3$

M due to wind $= 3 \times 23.13 = 69.39$ say .070 psf

$M = .070 \times 16.67^2/8 = 2.43$ 'k.

$f_{bx_1} = \frac{6.36 \times 12}{5.3} = 14.40$ ksi.

$f_{by} = 2.43 \times 12 / 8.3 = 3.51$ ksi

REF. PAGE

Maximum stress in the Combined member

$f_{bx} + f_{by} = 14.40 + 3.51 = 17.91 < 1.33 \times 21.6.$

Use C 6x8.2 with C 8x11.5 as shown.

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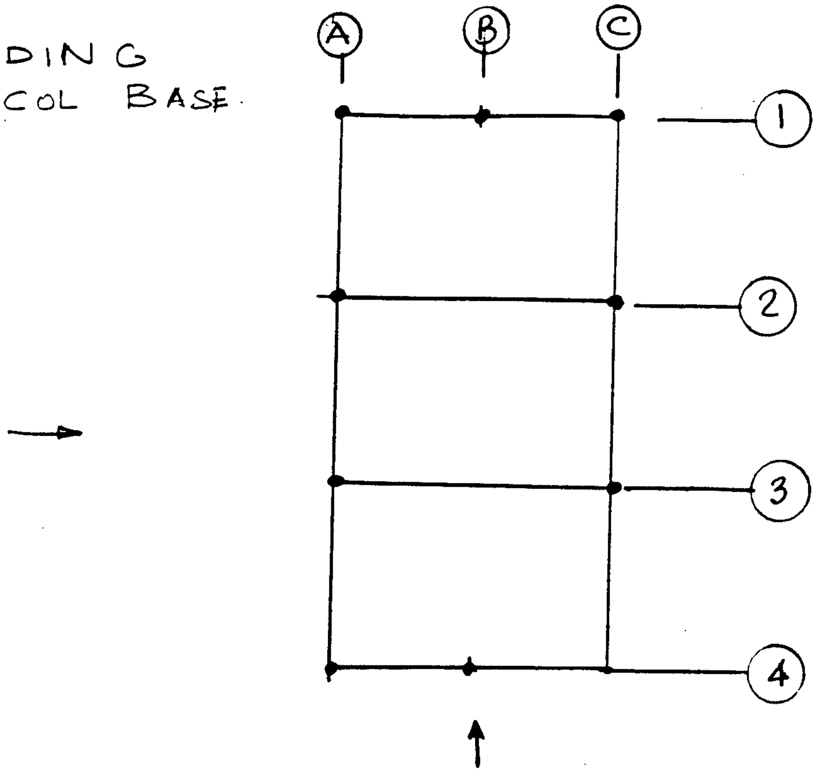
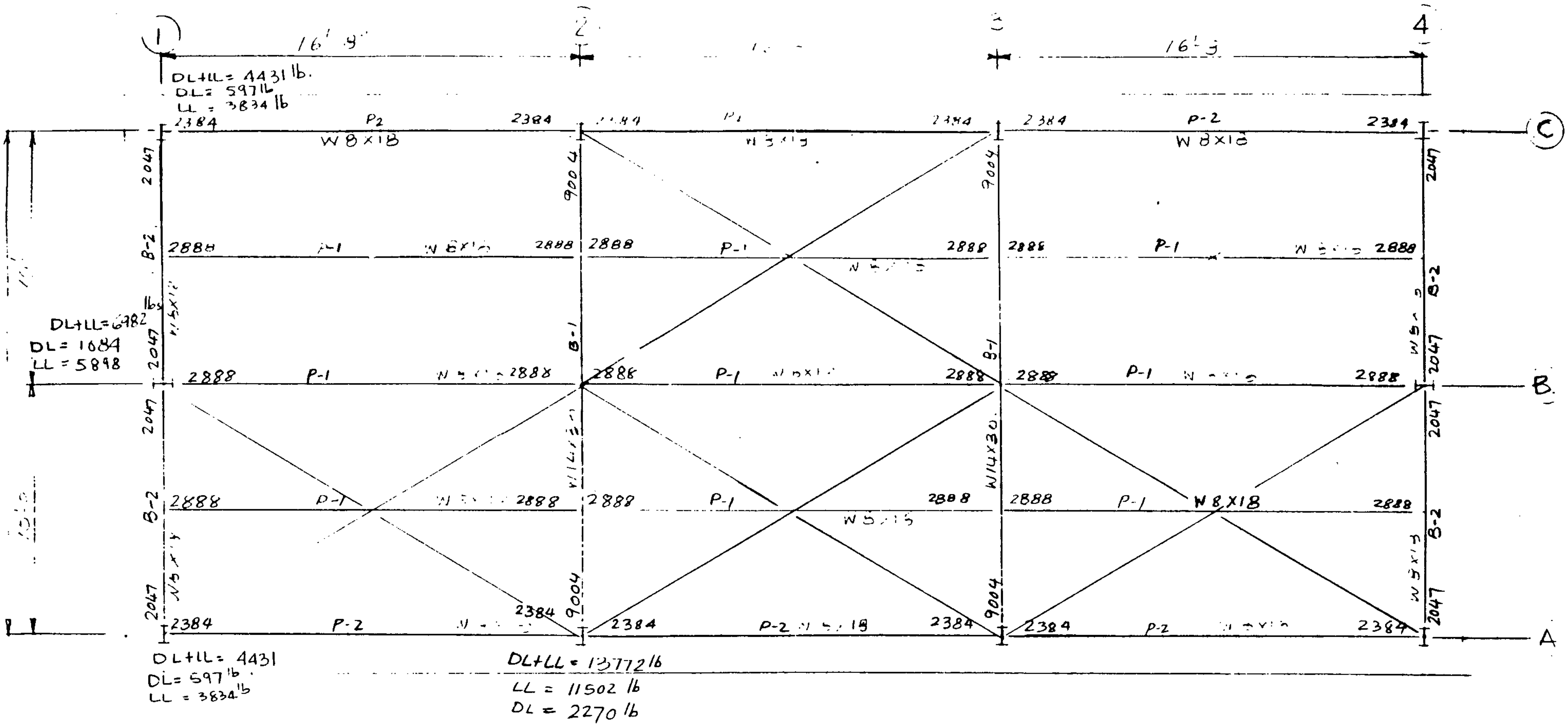
LOADING
AT COL BASE



COLUMNS / DESCRIPTION	A-1	B-1	C-1	A-2	C-2	A-3	C-3	A-4	B-4	C-4	
DEAD LOAD	1.55 k	3.04	1.55	5.42	5.42	5.42	5.42	1.55	3.04	1.55	
LIVE LOAD	3.83	5.90	3.83	11.5	11.5	11.5	11.5	3.83	5.90	3.83	
DL + LL.	5.38	8.94	5.38	16.92	16.92	16.92	16.92	5.38	8.94	5.38	
WIND UPLIFT	.83 ↑	1.28 ↑	.83 ↑	2.49 ↑	2.49 ↑	2.49 ↑	2.49 ↑	.83 ↑	1.28 ↑	.83 ↑	uplift.
WIND ⊥ TO LONG SIDE: HORIZONTAL	→ 7.48	( )	→ .35	→ 2.68	→ 1.67	→ 2.68	→ 1.67	→ 7.48	( )	→ .35	
VERTICAL	11.71 ↑	11.71 ↓						11.71 ↑	11.71 ↓		
WIND ⊥ TO SHORT SIDE											
HORIZONTAL	→ .147	→ .67	→ .147			→ 2.76	→ 2.76	→ .39	→ 1.78	→ .39	
VERTICAL				2.61 ↓	2.61 ↓	2.61 ↑	2.61 ↑				



LL+AL = 60psf

ROOF PLAN

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COL A-2, A 3, C-2, C-3

DL +LL. = 13772 lbs Page 28

Wt of siding = $168.5 \times 16.67 = 2809$

$(19 \times 6.5 + 3 \times 11.5 + 10.5)$ Tot. = 16581 lbs.
= 168.5'

Try with W 8X18

$S_x = 15.2 \text{ in}^3$ $A = 5.26 \text{ in}^2$
$S_y = 3.04 \text{ in}^3$ $d/A_f = 4.70$
$r_x = 3.43$ in
$r_y = 1.23$ in

$l_x = 19.08$

$l_y = 10'$

$l/r_y = \frac{10 \times 12}{1.23} = 97.56$

$l/r_x = \frac{19.08 \times 12}{3.43} = 66.75$

For $l/r_y = 97.56$ $F_a = 13.28$ ksi AISC 3-16

$f_a = \frac{16581}{5.26} = 3152.3 \text{ psi} = 3.15$ ksi

Column design - Wind Normal to the 50'-0 side.

It is a single story structure - Use the same value of wind force as the Girt design -

$p = 1.25 \times 18.5 = 23.13$ psf

Assume for conservativeness girts are continuous.

Wind load/ft on Col A-2 or A-3

$= 1.1 \times 16.67 \times 23.13 = 424.13$ lbs/ft

PROJECT Loring Airforce Base
SUBJECT FT-4 Process Building
Design of Column:

REF. PAGE

Mom. due to wind $= M_x = \frac{424.13 \times 19.25^2}{8} = 19646$ lbft-

(column is pinned at both end)

Max^m Vertical load on Column $=$ 16581 lb $=$ 16.581 k.

Max^m Mom $=$ 19.646 k'ft-

Try with W 8x18 $A = 5.26 in^2$

$S_x = 15.2 in^3$ $S_y = 3.04 in^3$

$r_x = 3.43 in$ $r_y = 1.23 in$ $d/A_f = 4.7.$

$L_c = 5.5$ L_u 9.9

$KL_x/r_x = \frac{1 \times 19.25 \times 12}{3.43} = 67.35$ $\quad kl_y/r_y = \frac{1 \times 10 \times 12}{1.23} = 97.56.$

Fa allowable $=$ 13.28 ksi. (AISC. page 3-16)

$f_a = \frac{16.581}{5.26} = 3.15$ ksi $\quad \frac{f_a}{F_a} = .2372$

$f_b = \frac{19.646 \times 12}{15.2} = 15.51$ ksi. $\quad F'_e = \frac{12 \pi^2 29000}{23 \times (67.35)^2} = 32.89$ ksi

Allowable bending stress $F_b = \frac{12 \times 1000 \times C_b}{Ld/A_f}$

$= \frac{12 \times 1000}{10 \times 12 \times 4.70} = 21.28$ ksi

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} = \frac{3.15}{13.28} + \frac{15.51}{\left(1 - \frac{3.15}{1.33 \times 32.89}\right) 21.28} = \frac{3.15}{13.28} + \frac{15.51}{19.75}$$

$= .2372 + .785 = 1.022 < 1.33$ ok.

Building subjected to wind force on 20' side.

Force acting on Col. from Bracing system:

axial force = 2.61^k.

Total D+L+W = 16.58+2.61 = 19.19

Wind force on the side wall outwards.

wind force/FT. = 1.1 × .5 × 18.5 × 16.67

Col - W8X18.

= 169.62 lbs/ft Say 170 lbs.

$M_W = \frac{.170 \times 19.25^2}{8} = 7.87$ kft

$f_a = \frac{19.19}{5.26} = 3.65$ ksi

$F'_e = 32.89$ (Page 30)

$f_b = \frac{7.87 \times 12}{15.2} = 6.21$ ksi.

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} = \frac{3.65}{13.28} + \frac{6.21}{\left(1 - \frac{3.65}{1.33 \times 32.89}\right) \times 21.28}$$

$$= .275 + \frac{6.21}{19.51} = .275 + .318 = .593 < 1.33$$

For Col A-2, A-3, C-2 and C-3

Use W8X18.

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Design of Column

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Col on line B-1 and B-4.

Wind normal to line 1

Vertical DL & LL on Col = 6982 lbs. Page 28
(from page 9 - 2x2047 + 2888)

Wt of siding and Girts $(6.5 \times 19.45 + 3 \times 11.5) = 161 \times 1.1 \times 10$
= 160.93 say 161 = 1771 lbs

Use W8x18 as col. Self wt = 18×19.25 = 347

Total axial load = 9100 lbs.

Wind force on the member same value as col A-2
= 23.13 lbs/sft.

Wind force / ft on Col = $1.1 \times 10 \times 23.13 = 254.43$ lbs/ft
(Assume Girt is continuous)

Mom. Due to wind = $\frac{.254 \times 19.25^2}{8} = 11.77$ k-ft

Try with W 18x8.

$S_x = 15.2 \text{ in}^3$ $S_y = 3.04 \text{ in}^3$ $A = 5.26 \text{ in}^2$

$r_x = 3.43$ in $r_y = 1.23$ in $d/A_f = 4.70$

$l_x = 19.25'$ (av)

$l_y = 10'$

$l/r_x = \frac{19.25 \times 12}{3.43} = 67.35$

$l/r_y = \frac{10 \times 12}{1.23} = 97.56$

Fa allowable = 13.28 ksi (AISC 3-16)

REF. PAGE

$$f_a = \frac{9100}{5.26} = 1730 \text{ psi}$$

$$f_b = \frac{11.77 \times 12 \times 1000}{15.2} = 9290 \text{ psi}$$

Allowable bending stress = 21.28 ksi

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} = \frac{1.73}{13.28} + \frac{9.290}{21.28} = .13 + .44$$

$$= .57 < 1.33$$

Design of col wind is perpendicular to the length of the building.

Axial force due to bracing system = 11.71^k (Page 16)

Vert. DL + LL + siding = 9.10^k

Total 20.81^k

Wind force on col (outward) = $101 \times 10 \times .5 \times 18.5$
= 101.75 lbs/ft Say 102 lbs.

$$M_W = \frac{.102 \times 19.25^2}{8} = 4.72 \text{ k ft.}$$

$$f_a = \frac{20.81}{5.26} = 3.956 \text{ ksi} \qquad f_b = \frac{4.72 \times 12}{15.2} = 3.73 \text{ ksi}$$

stresses are as follows Try with W 6 x 15

$A = 4.43 \text{ in}^2$ $S_x = 9.72$ $S_y = 3.11$

$r_x = 2.56$ $r_y = 1.46$ $d/A_f = 3.85$

$l/r_x = \frac{19.25 \times 12}{2.56} = 90.23$ $\qquad l/r_y = \frac{10 \times 12}{1.46} = 82.20$

$l_u = 12'$ $\quad l_c = 6.3'$

$F_a = 13.94$ ksi.

(90.23)

$l < l_u \qquad F_b = 21.6$ ksi. $\quad (.6F_Y)$

$f_a = \frac{20.81}{4.43} = 4.70$ ksi. $\qquad f_a/F_a = \frac{4.70}{13.94} = .337$

$f_{b_x} = \frac{4.72 \times 12}{9.72} = 5.83$ ksi.

Reduction in bending stress because f_a/F_a exceeds .15

$l/r_x = 90.23 \qquad F'_e = \frac{12 \pi^2 E}{23 \times (90.23)^2} = 18.323$ ksi. $\quad$ where $E = 20 \times 10^3$

Combining with axial compression and bending the stress ratios

$$\frac{f_a}{F_a} + \frac{f_b}{\left(1 - \frac{f_a}{F_e'}\right) F_b} \leq 1.0 \text{ for normal stress}$$

1.33 for (D+L+W)

$$\frac{4.70}{13.94} - \frac{5.83}{\left(1 - \frac{4.70}{1.33 \times 18.32}\right) \times 21.6} = .337 + \frac{5.83}{(1 - .193) \times 21.6}$$

$= .337 + .334 = .671 < 1.33$ ok.

use W6X15

REF. PAGE

Check D+L+W normal to Col. with W6X15

Max^m vertical load = 9100 lbs. = 9.1 kips

Max^m bending mom due to wind = 11.77 kft-

Member – W 6X15

$A = 4.43\ in^2$ $S_x = 9.72\ in^3$ $S_y = 3.11\ in^3$.

$r_x = 2.56$ $r_y = 1.46$ $d/A_f = 3.85$

$l/r_x = \frac{19.25 \times 12}{2.56} = 90.23$, $l/r_y = \frac{10 \times 12}{1.46} = 82.20$

$F_a = 13.94$ ksi.

$f_a = \frac{9.10}{4.43} = 2.054$ ksi $f_a/F_a = \frac{2.054}{13.94} = .147 < .15$

no reduction in allowable bending stress

$f_b = \frac{11.77 \times 12}{9.72}$

$= 14.53$ ksi.

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} = .147 + \frac{14.53}{21.6} = .147 + .67 = .817 < 1.33$$

ok Use W6X15 as column.

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Design of Column

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Design of col A-1, A-4, C-1 and C-4

REF. PAGE

Maximum Vertical DL and Live load

From roof = 4431 (Page 28

Load from siding = 16.33x6.5+3x11.5x16.33 = 669.53
(8'-4" +1'-6"+1'-6"+5)

self wt assume W6x15 = 290 lbs.

Total vert. DL+LL = 5390 lbs

Wind Normal to line A or C

Wind force = 1.25x18.5
= 23.13 lbs/ft²

Mom. due wind force.

(See page.

Wind force per ft = 23.13x 9.84 = 227.60 lbs.

Mom. due to wind force = $227.6 \times 10^2/8$ = 2845 lbft

(column is braced at 10'-0 height from the bottom

Try with W 6x15 Col.

Properties of the section.

$A = 4.43 \text{ in}^2$ $\qquad S_x = 9.72 \text{ in}^3$ $\qquad r_x = 2.56$

$d/A_f = 3.85$ $\qquad S_y = 3.16 \text{ in}^3$ $\qquad r_y = 1.46$

$$l/r_x = \frac{10 \times 12}{2.56} = 46.88 \qquad l/r_y = \frac{10 \times 12}{1.46} = 82.19$$

Fa allowable = 15.10 ksi. $\qquad f_a = \frac{5.39}{4.43} = 1.2167$ ksi

$$f_a/F_a = \frac{1.2167}{15.10} = .0805$$

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$$f_b = \frac{2.845 \times 12}{9.72} = 3.51 \text{ ksi} \quad \text{ok.}$$

$$f_a/F_a + f_b/F_b = .0805 + \frac{3.51}{21.6} = .0805 + .21 = .2905 < 1.33 \quad \text{ok.}$$

Check with axial load when wind ⊥ to line C

There is no mom but axial compression

Total vertical load due to wind = $11.71 + 5.390 = 17.1^k$

$$f_a = \frac{17.10}{4.43} = 3.86 \text{ ksi}$$ Stress is nominal.

Use W6X15 as corner post.

Wind perpendicular to shorter side line 1 or 4

$b = 6.5$ wind force $= 1.25 \times 18.5 = 23.13 \text{ lbs}/\text{ft}^2$

Wind force $= 6.5 \times 23.13 = 150.35 \text{ lbs}/\text{ft}^2$

$l = 10'$

$$M_W = \frac{.150}{8} \times 10^2 = 1.88'^k$$

$$f_a = \frac{5.39}{4.43} = 1.2167 \text{ ksi}$$

$$f_b = \frac{1.88 \times 12}{3.16} = 7.12 \text{ ksi}$$

$$f_a/F_a + f_b/F_b = \frac{1.2167}{15.10} + \frac{7.12}{21.6} = .0805 + .33 = .4105 < 1.33$$

Use W6X15 as Corner Column.

Max^m force on bracing

Vertical or horizontal $= 9.78^k$ (T), (Vertical)

$l = 19.44/2$ for roof $P_{roof} = 8.46^k$ (T)

Try with $3 \times 2\frac{1}{2} \times 1/4$ Connecting leg 3'' $r_{min} = .661$

$l = 9.72'$ $l/r_{min} = \frac{9.72 \times 12}{.661} = 176.46 < 300$ ok.

Tension Capacity.

Net area of angle $= \left\{1.31 - (.25 \times 3/4) - (\frac{1}{2} \times 1.125 \times 1/4)\right\} 22$

$= 1.31 - .19 - .14 = .98$ ✓.

Tension capacity $= .98 \times 22 = 21.56^k$. ok.

Use $3 \times 2\frac{1}{2} \times 1/4$ ∠ as bracing Member.

COL A-2, A-3, C-2 C-3

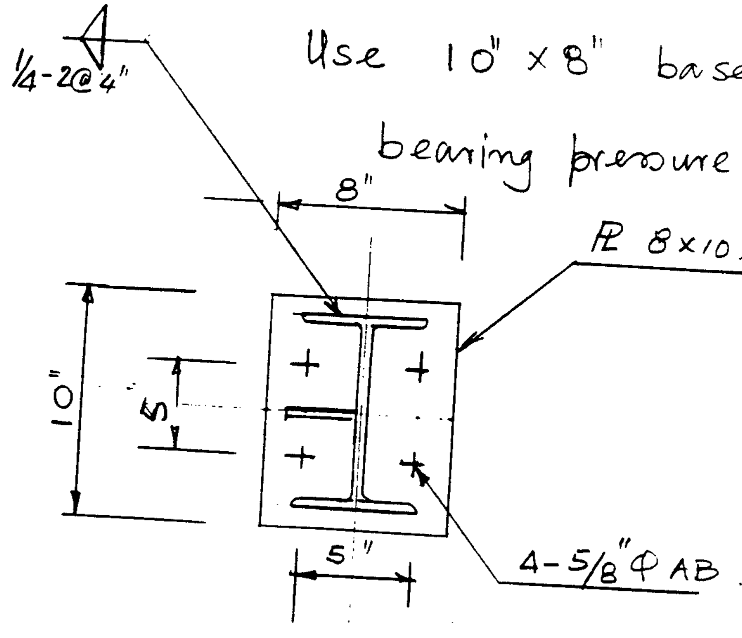
COL size W8x18.

1st. design f DL+LL. Concrete 4000psi

Max[m] Vert. load $= 16.92^k$.

Use 10" x 8" base plate

bearing pressure $= \dfrac{16.92}{10 \times 8} = .2115$ ksi



d = 8.14"
b = 5.25

$m = \dfrac{10-.95d}{2} = \dfrac{10-.95d}{2}$

$= 1.1335"$

$n = \dfrac{8-.8 \times 5.25}{2} = 1.9"$

m and n dimensions are small. $n > m$

$t_p = 2n\sqrt{f_p/F_y} = 2 \times 1.9\sqrt{\dfrac{.2115}{36}} = .291"$

Use 1/2" Plate.

Max[m] horizontal force $= 2.68^k$.

Net Uplift at the base $= (2.49+2.61) - 5.42 \times .8$.

$= 5.1 - 4.34 = .76^k$ (uplift)

CASE 2. Min DL + Wind uplift and horizontal force

Min. Vert. load $= .8 \times 1.55 = 1.24$

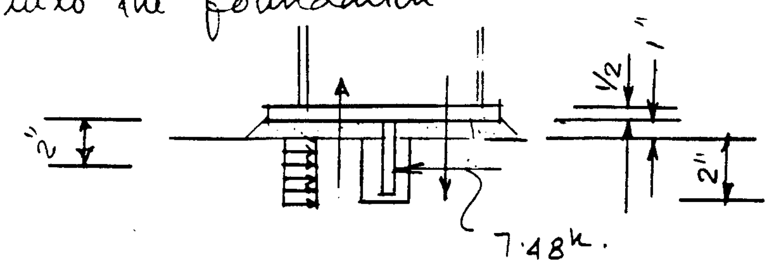
Wind uplift force $= 11.71 + .83 = 12.54^k$

Net uplift $= 12.54 - 1.24 = 11.3^k$

uplift force / bolt — 4 bolts are used.

Uplift / bolt $= 11.3/4 = 2.825^k$.

Horizontal shear $= 7.48^k$. Assume shear lug will be connected to plate to transfer the horizontal force into the foundation.



Assume uniform bearing pressure.

$$p = \frac{7.48}{2 \times 8} = .4675 \text{ psi}$$

$$M = .4675 \times 2 \times 2 = 1.87 \text{ kin}$$

$$t = \sqrt{\frac{6 \times 1.87}{27}} = .644'' \quad \text{use } 3/4'' \text{ Pl}$$

Weld shear force / in. $= \frac{7.84}{8 \times 2} = .49 \text{ k/in}$.

Force due to Mom

$Mom = 1.87^{k}\,in.$

$Torc = 1.87^{k}/in.$

$d = 3/4 + 1/4 = 1''$

$\text{Resultant weld} = \sqrt{1.87^2 + .49^2} = 1.933^{k}/in.$

Use 1/4" Weld each side.

Tension / bolt = 2.825^{k} —— Page 41

Add'l Tension due to shear lug.

$= \dfrac{7.48 \times 2}{5 \times 2} = 1.496^{k}/bolt$

Max^{m} tension $= 2.825 + 1.496 = 4.321^{k}.$

Use 3/4 dia bolt tension Capacity 8.8^{k} on gross area.

$F_T = 20$

(Tensile area = .334 Capacity = $20 \times .334 = 6.68^{k}$)

Check plate thickness.

$M = 4.321 \times 2.25 \times 2 = 19.44$ in k

$M = 19.44/8 = 2.43$ kin

$t = \sqrt{\dfrac{2.43 \times 6}{27.0}} = .73''$

Use 3/4" Thick Plate

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SUBJECT FT 4 - Process Building.

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COL B-1 & B-4.

Loading is similar to A-1 & A-4

Use the same base plate for the column and anchor bolts.

Col C-1 and C-4 DL +LL is same as A-1 and A-4. Use W8X18 column with 8"x10x1/2 PL.

Use 2-5/8" dia anchor bolts.

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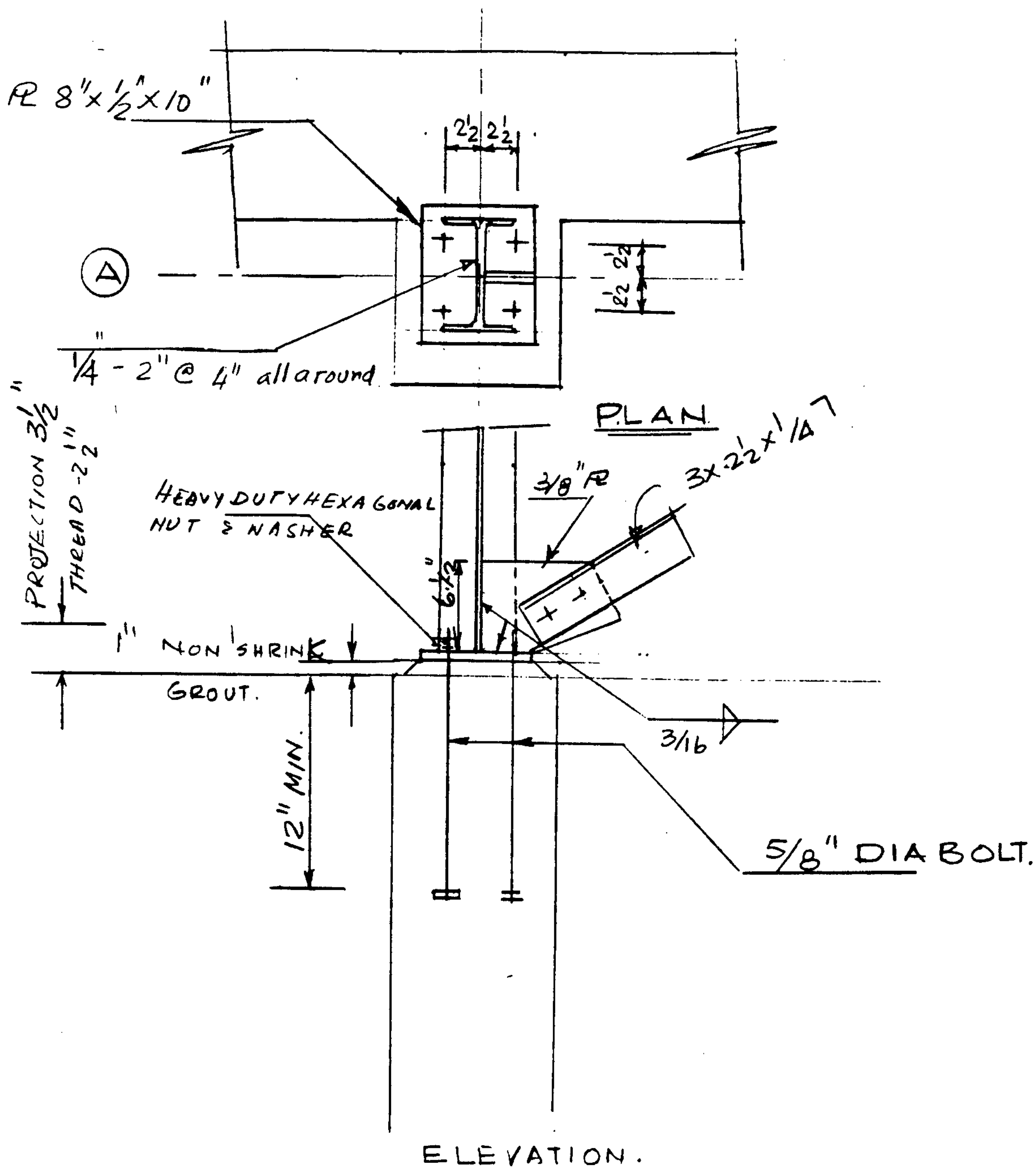
PROJECT LORING AIRFORCE BASE
SUBJECT FT-4 - TREATMENT BLDG.
BUILDING DESIGN - Detail of Base Plates and Bracing Connection

REF. PAGE



DETAIL SHOWN FOR COL BASE A-2

COL A-3, C2 AND C-3 ARE SIMILAR
FOR ORIENTATION SEE PLAN.

PROJECT LORING AFB.
SUBJECT F.T-4 TREATMENT BLDG.
BRACING CONN. TO COL BASE

REF. PAGE

Bracing. Connection All bracing $3 \times 2\frac{1}{2} \times \frac{1}{4}$.

Connection is with 2- ASTM A-325

Bolts. 3/4" dia single Shear Capacity
$= 7.51^k \times 2 = 15.1^k$

Tension Capacity of Member.

$A = 1.31 \, in^2$ $A_{net} = 1.31 - \left(1.25 \times .25 + \frac{13}{16} \times .25\right)$
$= 1.31 - .52 = .79$.

Capacity $= 22 \times .79 = 17.38^k$.

Max^m force on the bracing as per design 9.78^k.

Design the connection for 15^k.

F_H Horizontal force $= 15 \times \frac{16.67}{19.44} = 12.86^k$.

Used 3/16 Fillet weld both side. Capacity/in. $= .93 \times 6$
$= 5.57$.

Capacity/1/16 inch $= .3 \times \frac{.707}{16} \times 70 = .93^{ksi}$

Weld Capacity $= 4 \times 5.57 = 22.27$

Vertical comp $= 15 \times \frac{10}{19.44} = 7.72^k$

length of gusset plate 6 1/2 and same length of weld is provided.

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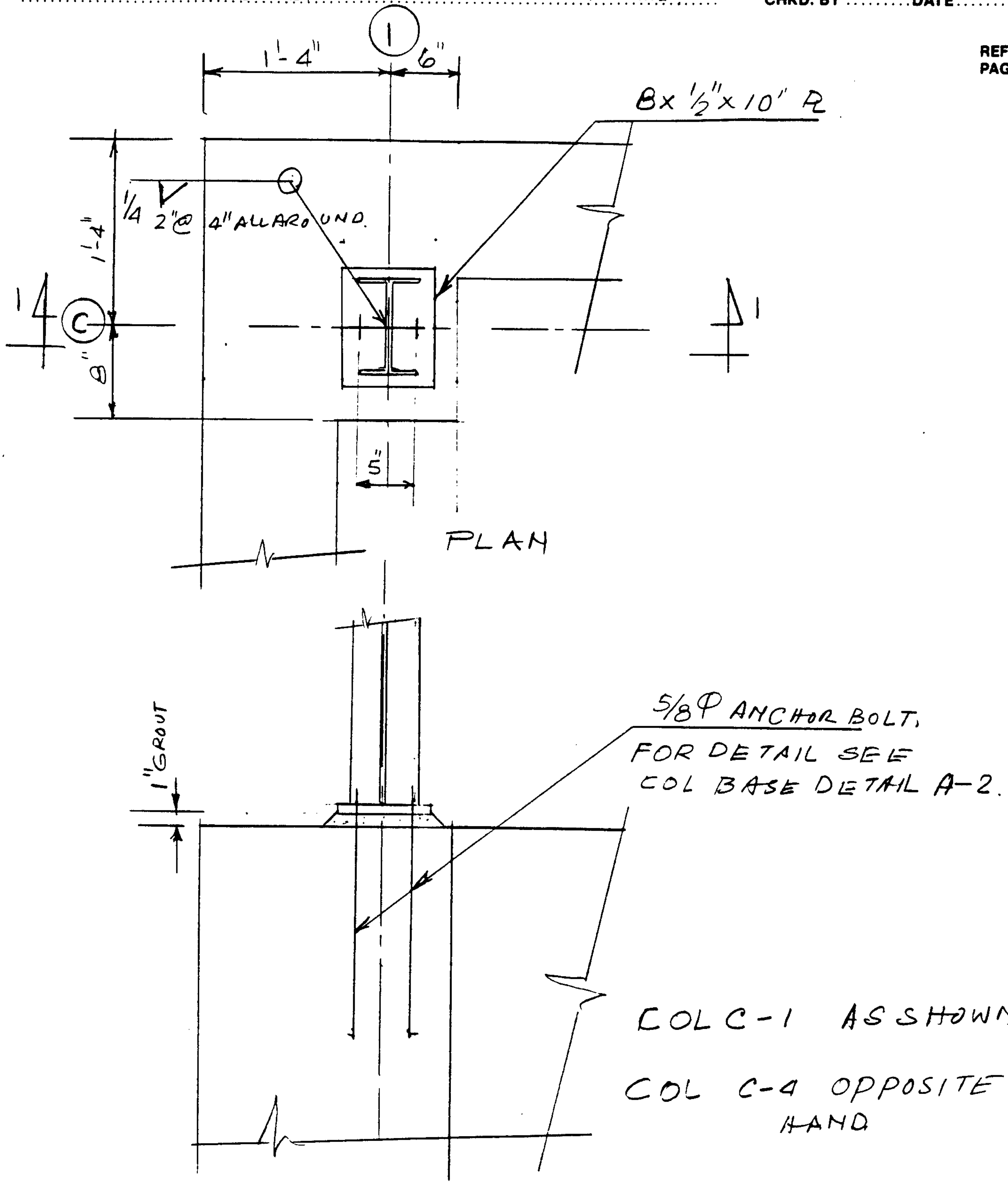
PROJECT LORING AFB

SUBJECT FT-4 TREATMENT BLDG.

BUILDING DESIGN – BASE PLATE DETAIL

REF. PAGE



COL C-1 AS SHOWN

COL C-4 OPPOSITE HAND

SEC 1-1

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PROJECT LORING AFB.
SUBJECT FT-4 TREATMENT BLDG.
BASE PLATE DETAIL

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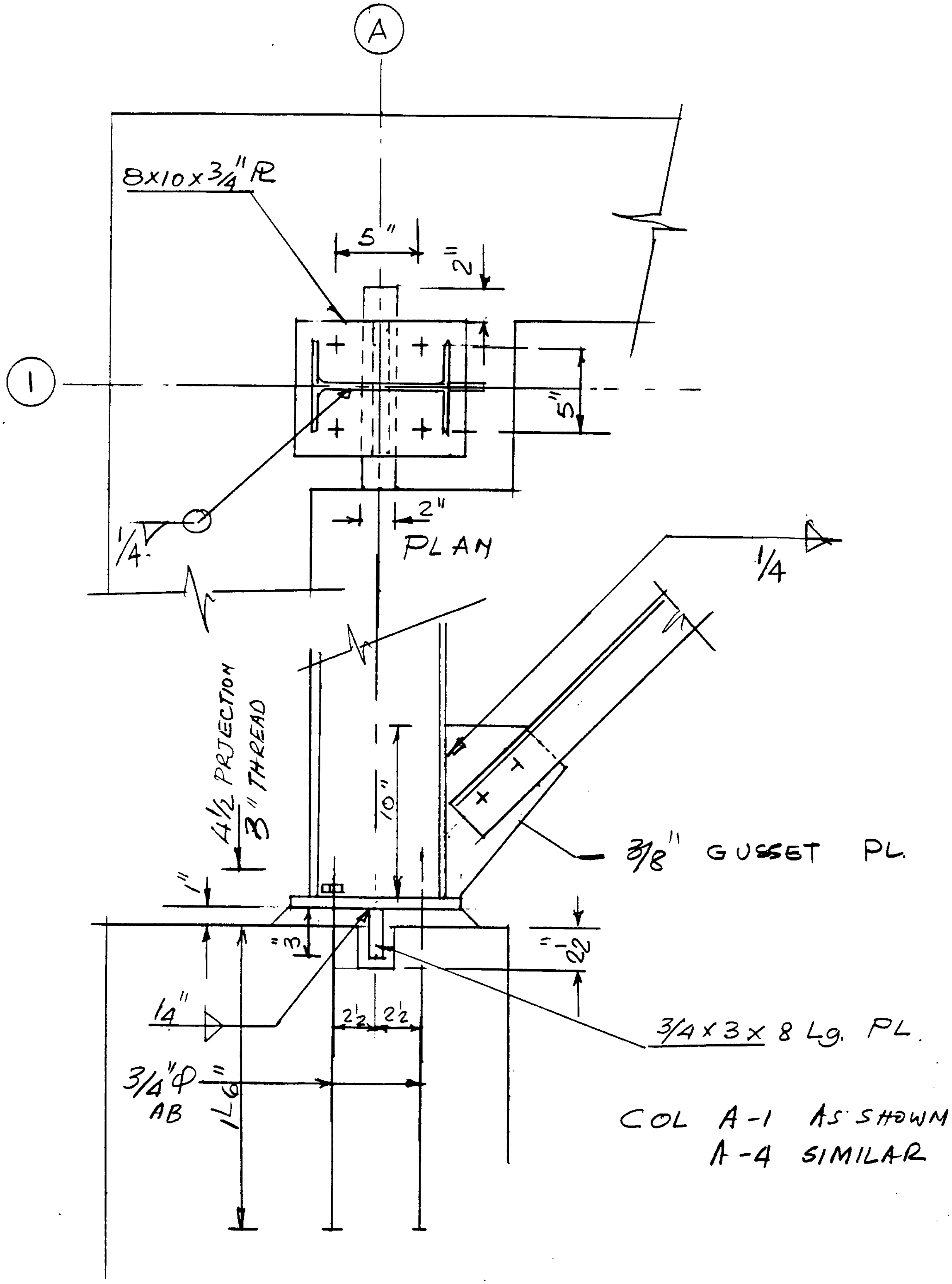

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Bracing Conn Detail.

Assume bracing is connected to flg of Colum only.

Force in bracing = 15^k Assume That the bracing is connected to flange only.

Length of Weld = 10" $e = 1''$

Maximum force for design = 15^k

$f_H = 15 \times 10 / 14.14 = 10.61k$

$f_V = 10.61k$ $M = 10.61 \times 1 = 10.61$ ink.

Check force on weld.

$$f_v = \frac{10.61}{10} = 1.06 k/in.$$

$$f_H = 10.61/10 = 1.06 k/in.$$

$$f_m = \frac{10.61 \times 6}{100} = .64$$

$$R_m = \sqrt{1.06^2 + (1.06 + .64)^2} = 2^k/in.$$

Use 1/4 weld on both side.

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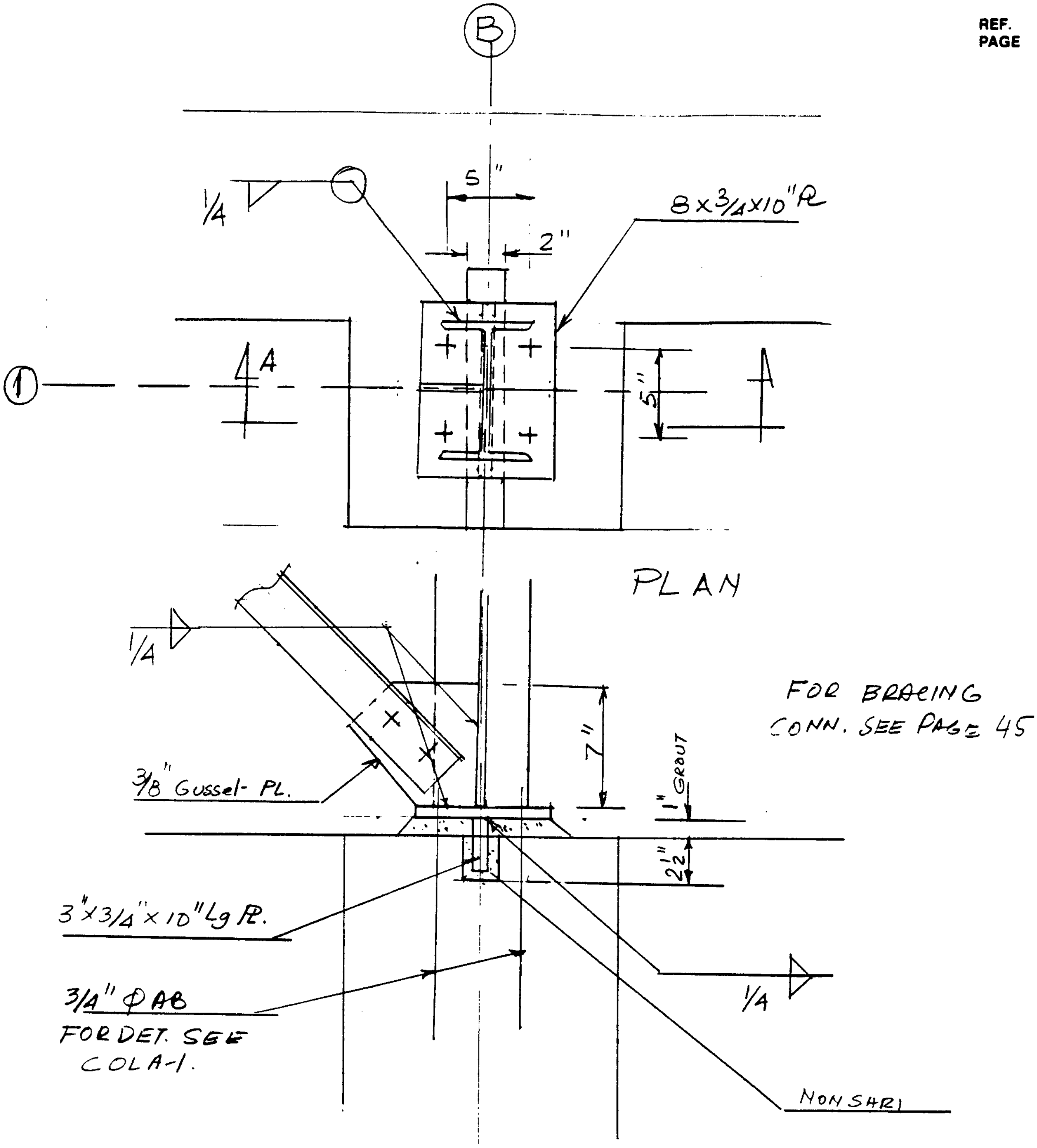
PROJECT LORING AFB.

SUBJECT FT-4 TREATMENT BLDG

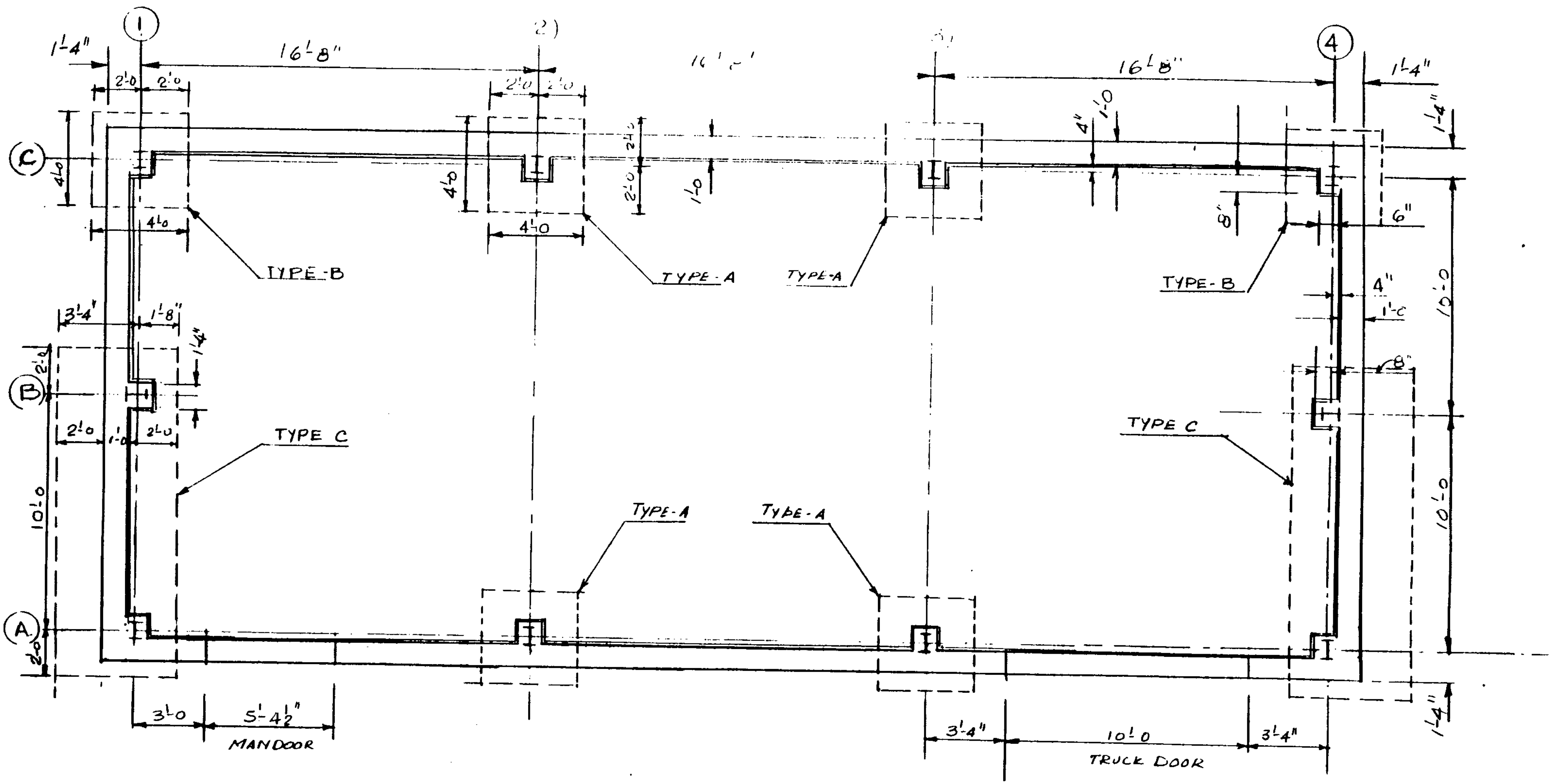
BASE PLATE DETAIL

REF. PAGE



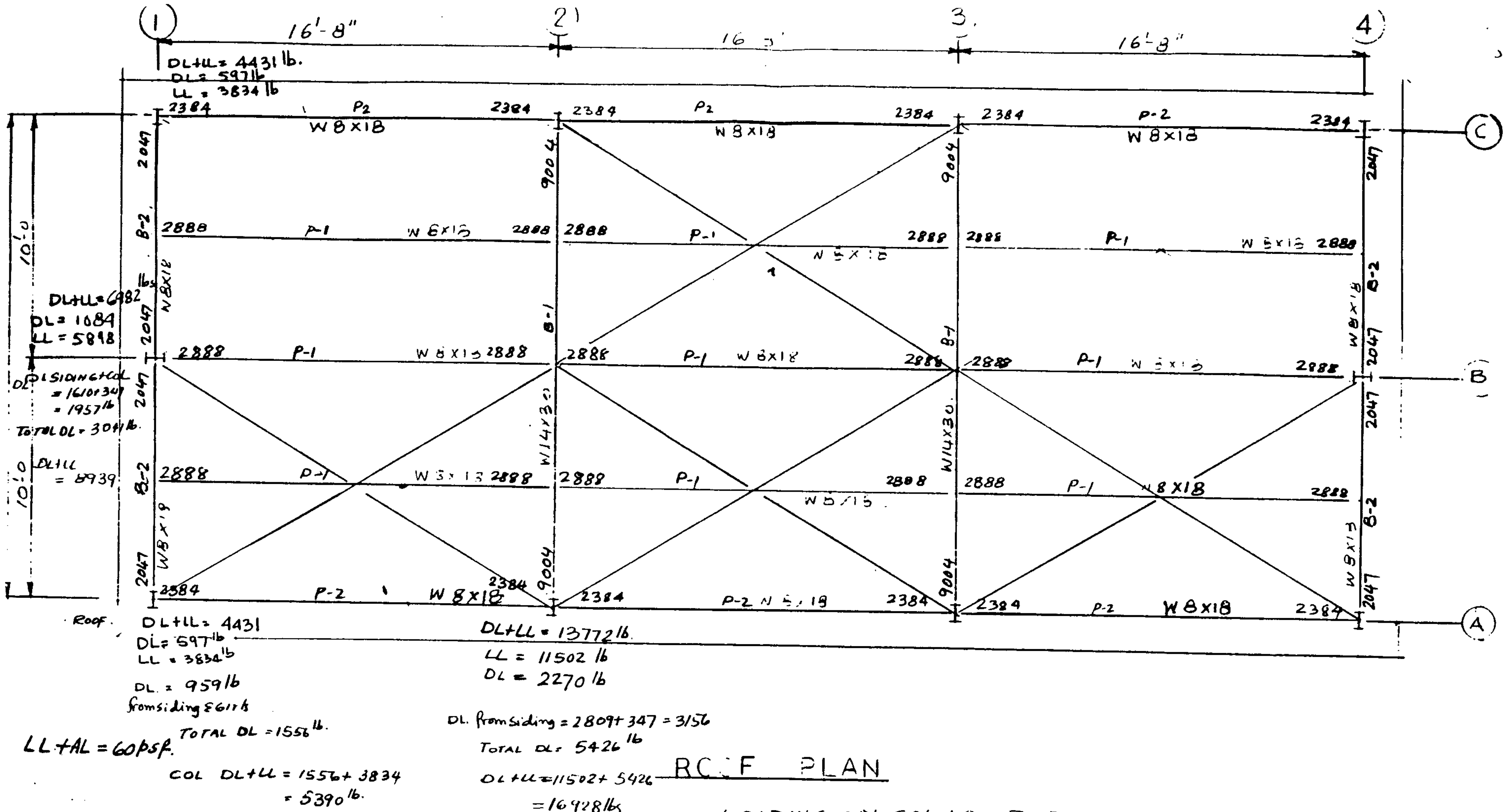
SECTION - A

DETAIL FOR B-1 IS SHOWN
DETAIL FOR B-4 SIMILAR.



PLAN

SCALE 1/4" = 1'-0"



ROOF PLAN

LOADING ON COL FROM ROOF

LL = 50 lbs/FT

AUXILIARY LOAD = 10 lbs/ft²

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SUBJECT FT4- Process Building.

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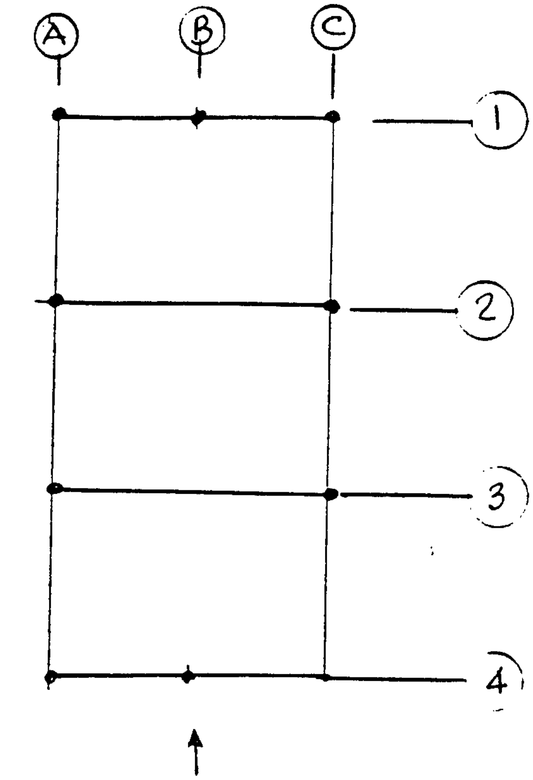
LOADING
AT COL BASE



COLUMNS / DESCRIPTION	A-1	B-1	C-1	A-2	C-2	A-3	C-3	A-4	B-4	C-4
DEAD LOAD	1.55	3.04	1.55	5.42	5.42	5.42	5.42	1.55	3.04	1.55
LIVE LOAD	3.83	5.90	3.83	11.5	11.5	11.5	11.5	3.83	5.90	3.83
DL + LL.	5.38	8.94	5.38	16.92	16.92	16.92	16.92	5.38	8.94	5.38
WIND UPLIFT	.83 ↑	1.28 ↑	.83 ↑	2.49 ↑	2.49 ↑	2.49 ↑	2.49 ↑	.83 ↑	1.28 ↑	.83 ↑
WIND ⊥ TO LONG SIDE: HORIZONTAL	$\overrightarrow{7.48}$	( )	$\overrightarrow{.35}$	$\overrightarrow{2.63}$	$\overrightarrow{1.67}$	$\overrightarrow{2.63}$	$\overrightarrow{1.67}$	$\overrightarrow{7.48}$	( )	$\overrightarrow{.35}$
VERTICAL	11.71 ↑	11.71 ↓						11.71 ↑	11.71 ↓	
WIND ⊥ TO SHORT SIDE										
HORIZONTAL	$\overrightarrow{.147}$	$\overrightarrow{.67}$	$\overrightarrow{.147}$			$\overrightarrow{2.76}$	$\overrightarrow{2.76}$	$\overrightarrow{.39}$	$\overrightarrow{1.78}$	$\overrightarrow{.39}$
VERTICAL				2.61 ↓	2.61 ↓	2.61 ↑	2.61 ↑			

PROJECT Loring Airforce Base

SUBJECT F.T. 4 Process Building

Foundation Design

REF. PAGE

Assumptions.

Concrete shall be 4000 psi air entrained.

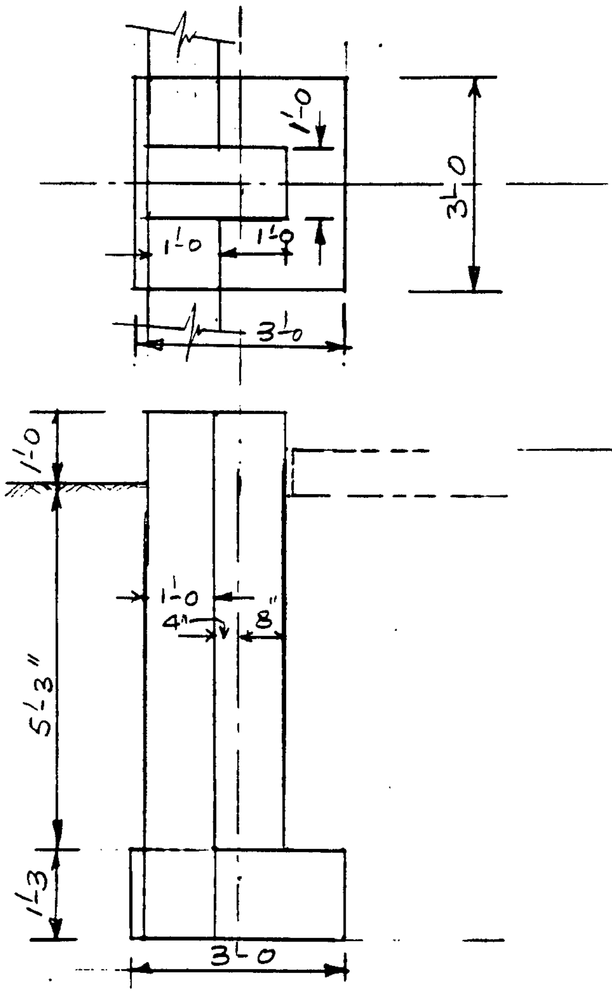
Reinforcing steel deformed Min $F_y = 60$ ksi

Foundation Bearing pressure = 4 kips/ft^2.

Frost depth = 6'-6"

Floor slab - Live load 500 psf plus the equipment load.

Foundation A 2 A 3 C-2 C-3. (Page 51,52)



CASE - I

Max^m DL + LL = 16.92^k

Wt concrete

Pier = 1x2x6.25x.15 = 1.88^k

Base Slab = 3x3x1.25x.15 = 1.69^k

Foundn Wall = 2x1x.15x6.25 = 1.88^k

backfill. Assume 110 lbs/cft

(9 - 2x1 - 2x1) 5.25x110 = 2.89^k

Total Vert. load 25.26^k

$$\text{Bearing pressure} = \frac{25.26}{3 \times 3} = 2.81^k/ft^2$$

PROJECT Loring Airforce Base
SUBJECT F.T. 4 Process Building
Foundation Design

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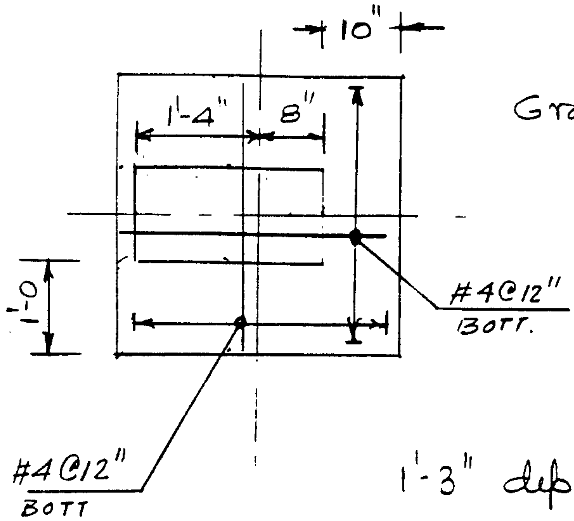


Gross mom at the face of col.

$= 2.81 \times 1^2/2 = 1.40'^k$

$A_s = \frac{1.40}{1.76 \times 11} = .07 \text{ in}^2$

Use #4 @ 12" both way. at bottom

1'-3" depth adequate by inspection.

Design of Pier – 24" x 12"

$P = 16.92^k \qquad e = .33$

Mom. due to vert. load $M = .33 \times 16.92 = 5.58 \text{ kft}$

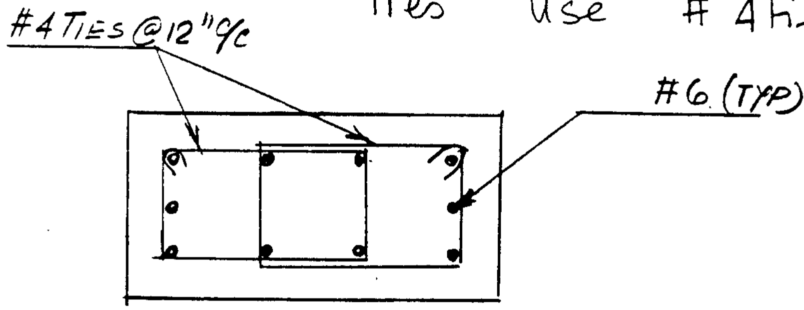
M due to Hor. Load $= 2.68 \times 6.25 = 16.75 \text{ kft}$

$M_{Tot} = 16.75 + 5.58 = 22.33 \text{ kft} \qquad A_s = \frac{22.33}{1.76 \times 21} = .60 \text{ in}^2$

Min. steel for Col $= 1\%$ $\qquad A_s = 24 \times 12 \times .01 = 2.88 \text{ in}^2$

Use 10 - #6 bar $\qquad A_s = 10 \times .43 = 4.3 \text{ in}^2$

Ties Use #4 ties 2/set @ 12" c/c.



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Wind ⊥ to line A orc. Take Min. Vertical load into account

Net reaction from Col = .8 × 5.42 - 2.49
= 1.85k ↓ (See pg 39)

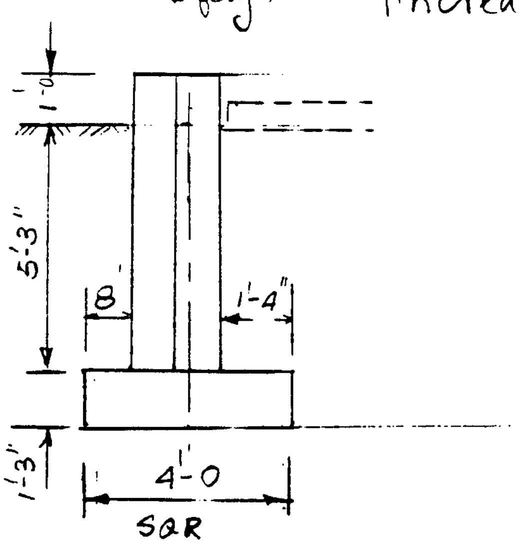
Hor. Force = 2.68k

Overturning Mom = 2.68 × 7.5 = 20.10 kft-

Stabilizing Mom

	Vert. load	x	Mom.
Col. Load	= 1.85	1.5	2.78
Concrete pier	= 1.88	1.84	3.46
Concrete Wall	= 1.88	2.34	4.40
Conc. Slab	= 1.69	1.5	2.54
Backfill soil	2.89	1.84/2	2.66
		Total	15.84 kft-

Factor of Safety less than 1
Footing size is inadequate to carry the load safely. Increase the footing size to 4'-0 × 4'-0'



Wt of Foundation

Concrete Pier - 1×2×6.25×.15 = 1.88k
Foundn Wall 3.0 × 1×6.25×.15 = 2.81k
Base slab 4.0×4.0×1.25× .15 = 3.0k
Backfill
[16 - (2×1 + 3×1)] × 5.25 × .11 = 6.35k

REF. PAGE

Overturning Moment

Hor^c force	height	H x y
2.68	7.5	= 20.10 kft

stabilizing Mom.

	Vert. Load	dist.	V x x = Mom.
Column DL (net)	= 1.85	2.0	3.70
Concrete pier	= 1.88	2.33	4.38
Concrete Wall	= 2.81	2.83	7.95
Base slab	= 3.0	2.0	6.0
Backfill			
(a) .67 x 4.0 x 5.25 x .11	= 1.55	3.67	5.69
(b) 1.33 x 4.0 x 5.25 x .11	= 3.08	.67	2.06
(c) 5.25 x 1 x 3. x .11	= 1.73	1.83	3.17
	Σ_V = 15.90		Σ_M 32.95

Factor of Saftey against overturning

$$= \frac{32.95}{20.10} = 1.64 > 1.5 \text{ ok}$$

let x be the dist where the resultant of the force is acting

$$x = \frac{32.95 - 20.10}{15.90} = .81$$

PROJECT Loring Air Force Base.
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Foundation design.

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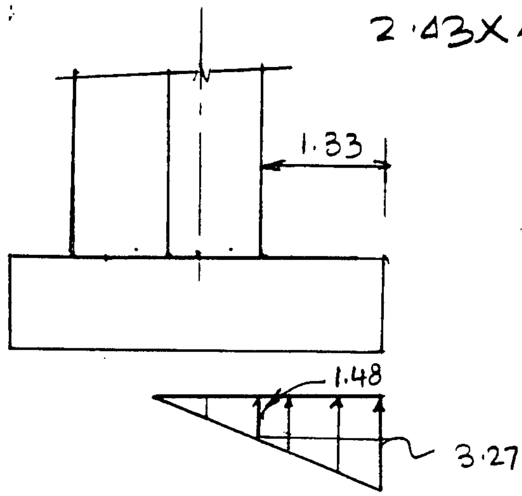
$e = 2 - .81 = 1.19$

$3x = .81 \times 3 = 2.43$ ft < 4.0 tension exist

Max^m pressure $= \dfrac{2 \times 15.90}{2.43 \times 4} = 3.27\ k/ft^2$



Mom at the face of Col. (RHS). $= 1.48 \times \dfrac{1.33^2}{2} + 1.79 \times \dfrac{1.33}{2} \times \dfrac{2}{3} \times 1.33$

$= 1.31 + 1.06 = 2.37$ kft

$A_s = \dfrac{2.37}{1.76 \times 11} = .12\ in^2$ Use # 4 @ 12" bott. bothway

For the Calculation of top steel.

Cantilever length $= 1'\text{-}6$

Max^m load $= 1.25 \times .15 + 5.25 \times .11 = .19 + .58 = .77\ k/ft^2$

$M = .77 \times 1.5^2/2 = .87$ kft

$A_s = \dfrac{.87}{1.76 \times 12} = .04$ use # 4 @ 1'-3" Top bothway

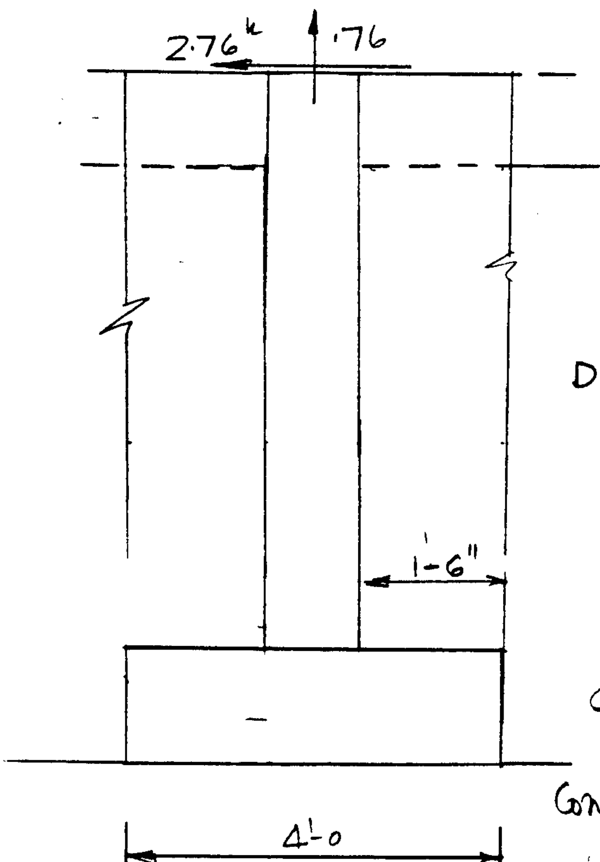
Wind perpendicular to line 1 or 4

Maximum uplift force = 2.61+2.49 = 5.10^k

Dead load = 5.42×.8 = 4.34^k

Net upward force = 5.10 − 4.34 = .76 ↑

Horizontal force = 2.76^k



Overturning Mom.

Due to uplift force:

F	x	Fx
.76	2	= 1.52

Due to horizontal force:

H	Y	H×y
2.76	7.5	20.70

Total overturning Mom. = 20.70+1.52
= 22.22 k-ft

Calculation of Stabilizing Mom.

	V	x	Vx
Conc. Pier	= 1.88	2	3.76
Conc Wall	= 8.25	2	16.5
Conc. Slab	= 3.0	2	6.0
Back fill	= 6.36	2	12.72
	ΣV = 19.49		38.98

Assume at least 8' length of wall will be effective since it will be monolithically poured.

W = 8×.15×6.25+4×.15×1.25
= 8.25

Factor of Saftey against overturning

$$FS = \frac{38.98}{22.22} = 1.75$$

let x be the dist where the resultant

act $x = \dfrac{38.98 - 22.22}{19.49 - .76} = \dfrac{16.76}{18.73} = .89$

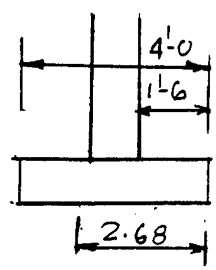
$e = 2.0 - .89 = 1.11 > b/6$ tension exist.

$3x = .89 \times 3 = 2.68$

Max^m pressure on the base $= \dfrac{2 \times 18.73}{4 \times 2.68}$

$= 3.49 \, k/ft^2$

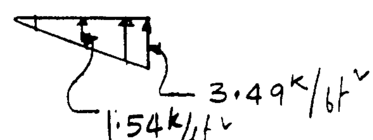
Neglect the perimeter wall.



pressure at end $3.49 \, k/ft^2$

pressure at the face of Col.

$p = \dfrac{3.49}{2.68} \times 1.18 = 1.54 \, k/ft^2$



Mom $= 1.54 \dfrac{\times 1.5^2}{2} + 1.95 \dfrac{\times 1.5}{2} \times \dfrac{2}{3} \times 1.5$

$= 1.73 + 1.462 = 3.19$ kft

$A_s = \dfrac{3.19}{1.76 \times 11} = .164$ Use #4 @ 12" c/c both.

(ignore selfwt + overburden)

overburden + Conc slab #/ft $= .15 \times 1.25 + 5.25 \times .11 = .1875 + .5775$

$= .765 \, k/ft^2$

Mom $= .765 \times 1.5^2/2 = .86$ kft

$A_s = \dfrac{.86}{1.76 \times 12} = .041 \, in^2$ Use #4@12

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Pier design. Axial load is negligible.

Mom. due to horizontal force $= 2.76 \times 6.25$
$= 17.25$ kft.

Torsional Mom $= .33 \times 2.76 = .91$ kft. #4 ties will be enough to take care of torsional effect.

Reinforcing steel due to bending

$$= \frac{17.25}{1.76 \times 9} = 1.08 \text{ in}^2$$

4 #6 @ $4 \times .23 = 1.72 \text{ in}^2 > 1.08$ ok

Use the same steel for pier as shown in page — 54

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Foundation on line 1 & 4
Col A-1 B-1 and A-4, B-4

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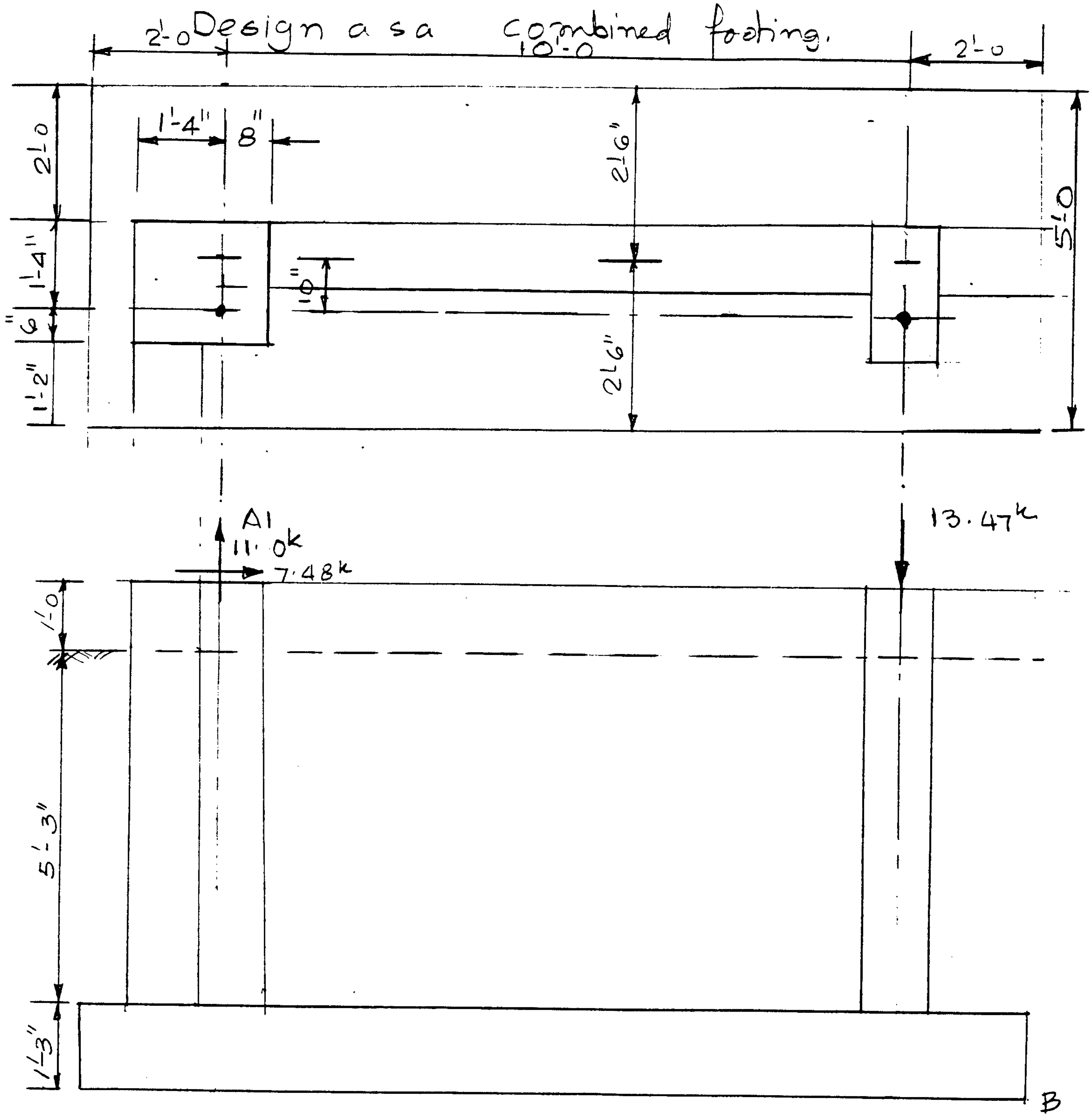
Design as a combined footing.



Force on Line A-1

Horizontal Force $= 7.48^k \rightarrow$

Wind uplift $= 11.71 + .83 = 12.54^k \uparrow$

Dead load $= 1.55^k \downarrow$

uplift $= 12.54 - 1.55 = 11.0$

Force on Line B-1

Vertical load due to wind $= 11.71 - 1.28 = 10.43^k$

Vertical load due to DL only $=$ 3.04

13.47 K.

calculation of overturning Mom due to Wind uplift and Wind horizontal force

(a) due to vertical uplift

Mom. about B.

	V	x	Vx
Vert. load	11.0	12	= 132.0

Due to hor. load.

H	Y	
7.48	7.5	56.1

Total overturning Mom $= 132.0 + 56.1 = 188.10$ k FT.

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Calculation of Vert. load and Stabilizing Mom.

	Vert load	X	V x
1. Col. B-1	13.47	2	26.44
Base Slab. $5 \times 14 \times 1.25 \times .15 =$	13.125	7	91.875
Wall bet. Col.			
$8.84 \times 6.25 \times 1 \times .15 =$	8.29	6.92	57.35
$1.5 \times 6.25 \times .15 \times 1 =$	1.40	.75	1.055
Col. A-1			
$2 \times 1.84 \times 6.25 \times .15 =$	3.45	12.33	42.54
Col. B-1 $2 \times 1 \times 6.25 \times .15 =$	1.875	2	3.75
Back fill outside			
$2 \times 5.25 \times 14 \times .11 =$	16.17	7	113.19
Back fill inside			
$2 \times 5.25 \times .11 \times 8.84 =$	10.21	6.92	70.65
$2 \times 1.5 \times 5.25 \times .11 =$	1.73	.75	1.30
behind Col. B-1			
$1 \times 1 \times 5.25 \times .11 =$	0.58	2.0	1.16
Col A-1			
$2 \times 5.25 \times .11 \times 1.16 =$	1.34	12.33	16.52
$3 \times .67 \times 5.25 \times .11 =$	1.16	13.67	15.87
	72.80^k		Σ 442.71 k-ft

NB. This is 442.2

No change in Calc made.

Factor of safety against overturning

$$= 442.71 / 188.10 = 2.35$$

Let x be the distance where the resultant act.

$$x = \frac{442.71 - 188.10}{72.8 - 11.0} = \frac{254.61}{61.80} = 4.12$$

$$e = 7 - 4.12 = 2.88 \quad < 14/6 \therefore \text{ Tension exist}$$

$$L = 3x = 3 \times 4.12 = 12.36$$

Max^m pressure on the foundation/ SF $= \dfrac{61.8}{1/2 \times 5 \times 12.36} = 2.0$

Calculation of SF and BM.

For simplicity assumptions are made ① such that total DL has been distributed uniformly, ② small eccentricity of pier load has been neglected in the longitudinal direction only.

$$DL / \text{running foot} = \frac{73.9 - 13.47}{14} = 4.32 \text{ K/FT.}$$

Ordinate of pressure at pt. 2 = .71 K/ft²

at pt 3 = 1.19 K/ft²

at pt 4 = 1.68 K/ft²

at pt 5 = 2 K/ft².

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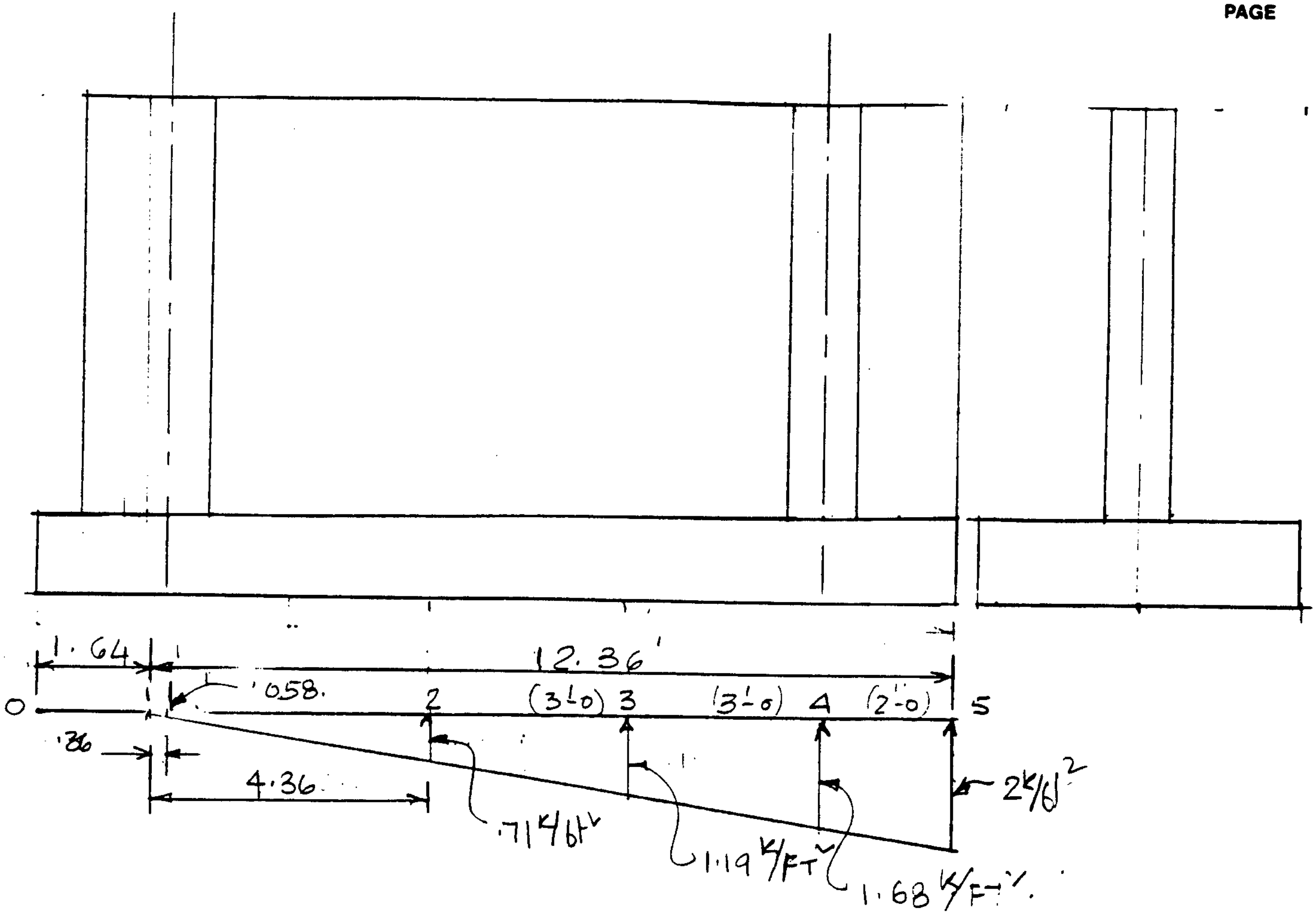
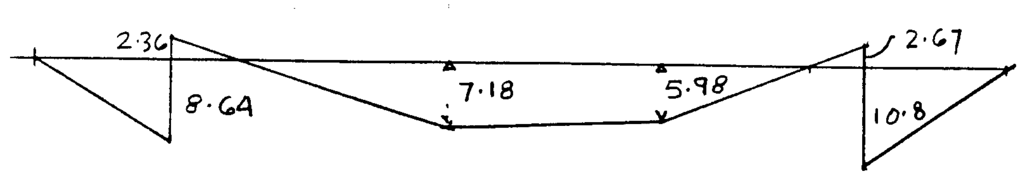
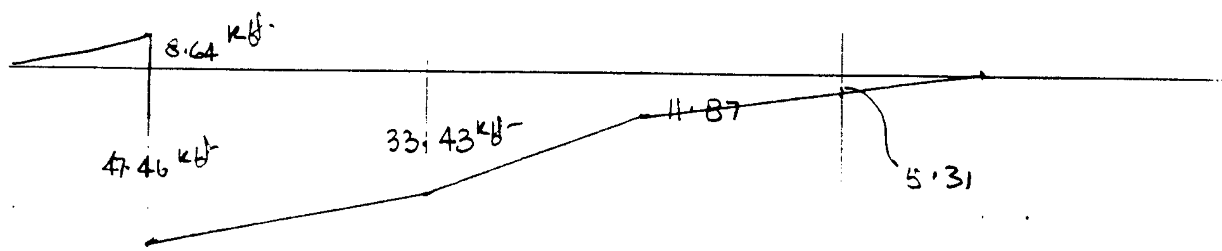




SF DIAGRAM.



Mom. diagram.

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Calculation of SF and Mom.

PT. 0 SF = 0 M = 0.

PT 1 SF to the left of pt 1 = 4.32 × 2 = 8.64 ↓

(effect of pressure on .36 ft has been ignored for pt 1).

SF to the right of pt 1 = 11↑ − 8.64 = 2.36 ↑

Mom. at p^- = 7.48 × 7.5 − 4.32 × $2^2/2$ = 56.10 − 8.64
= 47.46

at left of pt 1 = 4.32 × $2^2/2$ = 8.64

Point 2.

SF at pt 2 = 4.32 × 6 ↓ − 11.0 ↑ − .71 × 4.36 × 5/2 ↑
= 25.92 ↓ − 7.74 − 11.0 = 7.18 ↓

Mom. at Pt 2 = 11 × 4 + 7.48 × 7.5 + 7.74 × $\frac{4.3}{3}$ − 4.32 × $6^2/2$
= 44 + 56.10 + 11.09 − 77.76 = 33.43 k ft

Point 3

SF at pt 3 = −11 − 1.19 × $\frac{7.36}{2}$ × 5 + 9 × 4.32 = −11 − 21.90 + 38.88
= 5.98 ↓.

Mom at pt 3 = 11 × 7 + 7.48 × 7.5 + 21.9 × $\frac{7.36}{3}$ − 4.32 × $9^2/2$
= 77 + 56.10 + 53.73 − 174.96 = 11.87

PT. 4

SF at 4 to the left $= -11 - 1.68 \times \frac{10}{2} \cdot 36 \times 5 + 12 \times 4.32$

$= -11 - 43.51 + 51.84 = -2.67 \downarrow$

SF to the right of 4 $= 13.47 \downarrow - 2.67 = 10.80 \downarrow$

Mom. at Pt 4 $= 11 \times 10 + 7.48 \times 7.5 + 43.51 \times \frac{10.36}{3} - \frac{4.32 \times 12^2}{2}$

$= 110 + 56.10 + 150.25 - 311.04 = 316.35 - 311.04$

$= 5.31$ kft.

Calculation of Reinforcing.

Reinforce in transverse dir.

(a) Bottom steel.

Cantelever $M = \frac{2 \times 2^2}{2} = 4$ kft.

use av. $2^k/ft^2$

$A_s = \frac{4}{1.76 \times 11.5} = .20$ use

#4 @ 12"

(b) top steel

Load / $ft^2 = \frac{4.32}{5} = .86\ ^k/ft^2$.

Cantilever Mom $= .86 \times 2^2/2 = 1.72$ kft

$A_s = \frac{1.72}{1.76 \times 11.5} = .08\ in^2$

Use #4 @ 1'-3" c/c.

RIB DESIGN.

Max^m Mom. = 47.46

$A_s = \frac{47.46}{1.76 \times 86} = .31$

Use 2 #5 @ bott and top.

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PROJECT Plattsburgh A F B
SUBJECT F.T. 4 Process Building
Foundation Design:

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COL B-1. or B-4

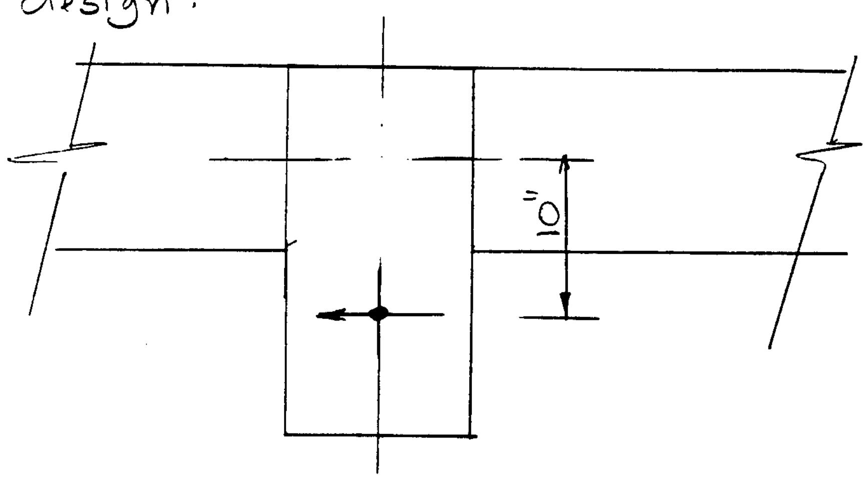
trans verse steel under the base = $\cdot 67 \times 7.5 = 5.03$ kft.

$$A_s = \frac{5.03}{1.76 \times 11.5} = .25\ in^2$$

NB. the above mom. due to wind will be distributed on 4'-0 wide base. $As/ft = .25/4 = .0625\ in^2$.

#4 @ 12" is satisfactory.

Pier design.



Lateral steel ties shall be designed to with stand the torisional effect. Since the torsional moment is very small its effect is neglected. Closed ties are used. Normal shear stress is negligble. Pier steel will be designed assuming cantilever from the base without any support from the perimeter wall.

PROJECT Loring Airforce Base

SUBJECT FT-4 Process Building Design

Foundation Design

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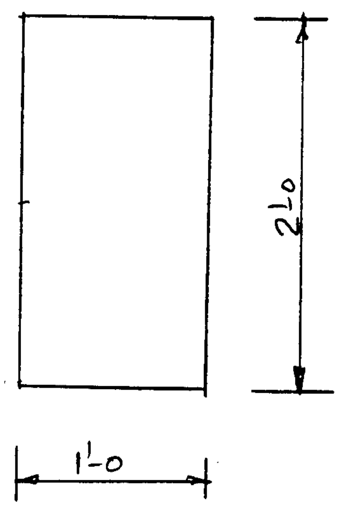
Design of pier.

$M_W = 7.48 \times 6.25 = 46.75$ kft

$U = 11.0^k$ Tension



Design as a beam col

$f_s = 24000$ psi $n = 8.0$

$f_c = .45 \times 4000 = 1800$ psi

$d = 9''$ $d' = 2''$

$d'' = 4$

$$e = \frac{12M}{N} + d'' = \frac{12 \times 46.75}{-11} + 4'' = -51 + 4 = -47''$$

$$E = \frac{e}{12} = \frac{-47}{12} = -3.92 \text{ ft}.$$

From table I Working stress design. for 24000/8.0/1800.

$K = 295$

From table 4 working stress design for $b \times d = 24 \times 9.5$

$F = .18$

$NE = (-3.92) \times (-11) = 43.08$

$KF = .18 \times 295 = 53.10$

$NE - KF = -10.02$ Since $NE - KF$ is $-$ve

no compressive reinforce is required.

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PROJECT Loring Air Force Base
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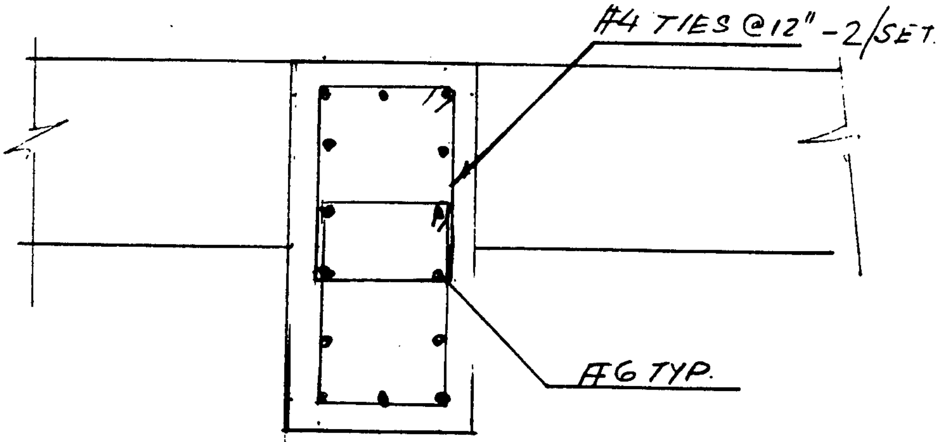
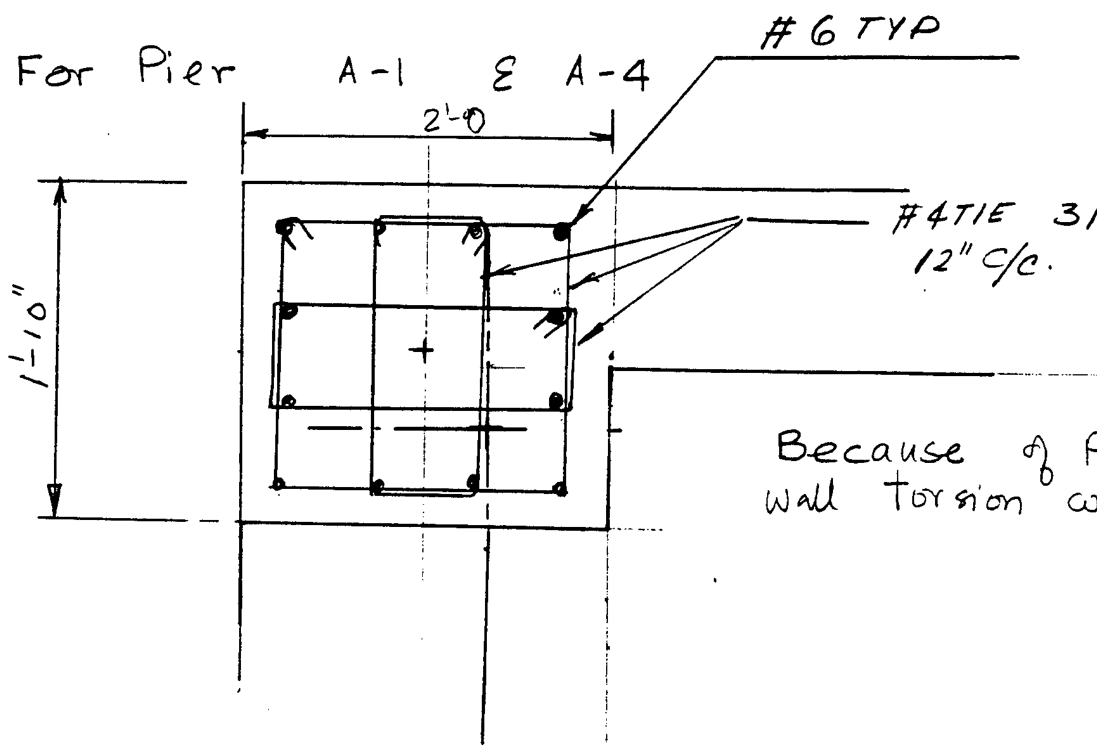
$$A_s = \frac{43.08}{1.76 \times 9.5} = 2.58\ in^2$$

Use 6#6 $A_s = 6 \times .44 = 2.64\ in^2$



For Pier A-1 & A-4



Because of Perimeter wall Torsion was neglected.

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PROJECT Loring A FB.
SUBJECT F.T.-4 Process Building Design.
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Design for tension and Mom

$M_w = 46.75$ kft — Page 18

$V = 11^k$ (T.)

Design as a beam col

$f_s = 20{,}000$ psi
$n = 8$
$f'_c = 1800$ psi

$e = \frac{12M}{N} + d'' = \frac{12 \times 46.75}{-11} + 9''$

$= -51 + 9 = -42''$

$d = 21 \quad d' = 3''$

$d'' = 9''$

$E = \frac{e}{12} = \frac{-42}{12} = -3.5'$

From table 1 Working stress Design Handbook

For 24000/8/1800 $K = 295$

From table 4 $b \times d = 22 \times 21$

$F = .8235$

$NE = (-3.5)(-11) = 38.5$ k ft

$KF = 295 \times .8235 = 242.93$

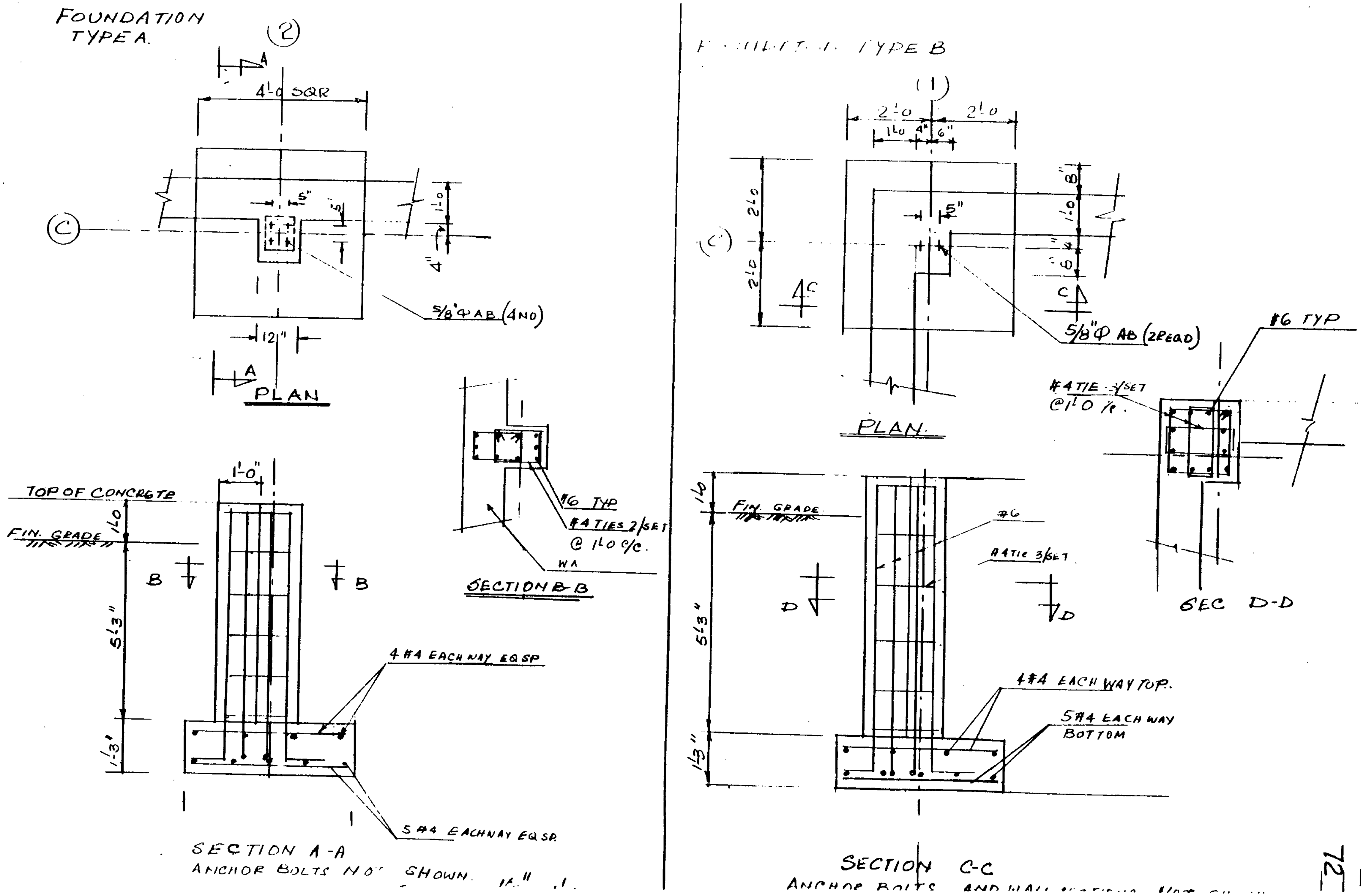
$KF > NE$ no compression reinforcement reqd.

$A_s = \frac{38.5}{1.76 \times 21} = 1.04 \text{ in}^2$

1% Steel $= 24 \times 22 \times .01 = 5.28 \text{ in}^2$

Use 12 # 6, $A_s = 12 \times .44 = 5.28 \text{ in}^2$

FOR C-1 & C-4 USE SAME STEEL AS A-1 & A-4.


FOUNDATION TYPE A.
4'-0 SQR
5"
1'-0
4"
5/8"Φ AB (4 NO)
12"
PLAN
TOP OF CONCRETE
FIN. GRADE
1'-0"
1'0
5'-3"
1'-3'
4 #4 EACH WAY EQ SP
5 #4 EACHWAY EQ SP.
SECTION A-A
ANCHOR BOLTS NOT SHOWN.
#6 TYP
#4 TIES 2/SET @ 1'-0 c/c.
SECTION B-B
TYPE B
2'-0
1'-0
4"
6"
5"
8"
5/8"Φ AB (2 REQD)
PLAN.
#6 TYP
#4 TIE @ 1'-0 c/c.
SEC D-D
FIN. GRADE
#6
#4 TIE 3/SET
5'-3"
1'-3"
4 #4 EACH WAY TOP.
5 #4 EACH WAY BOTTOM
SECTION C-C

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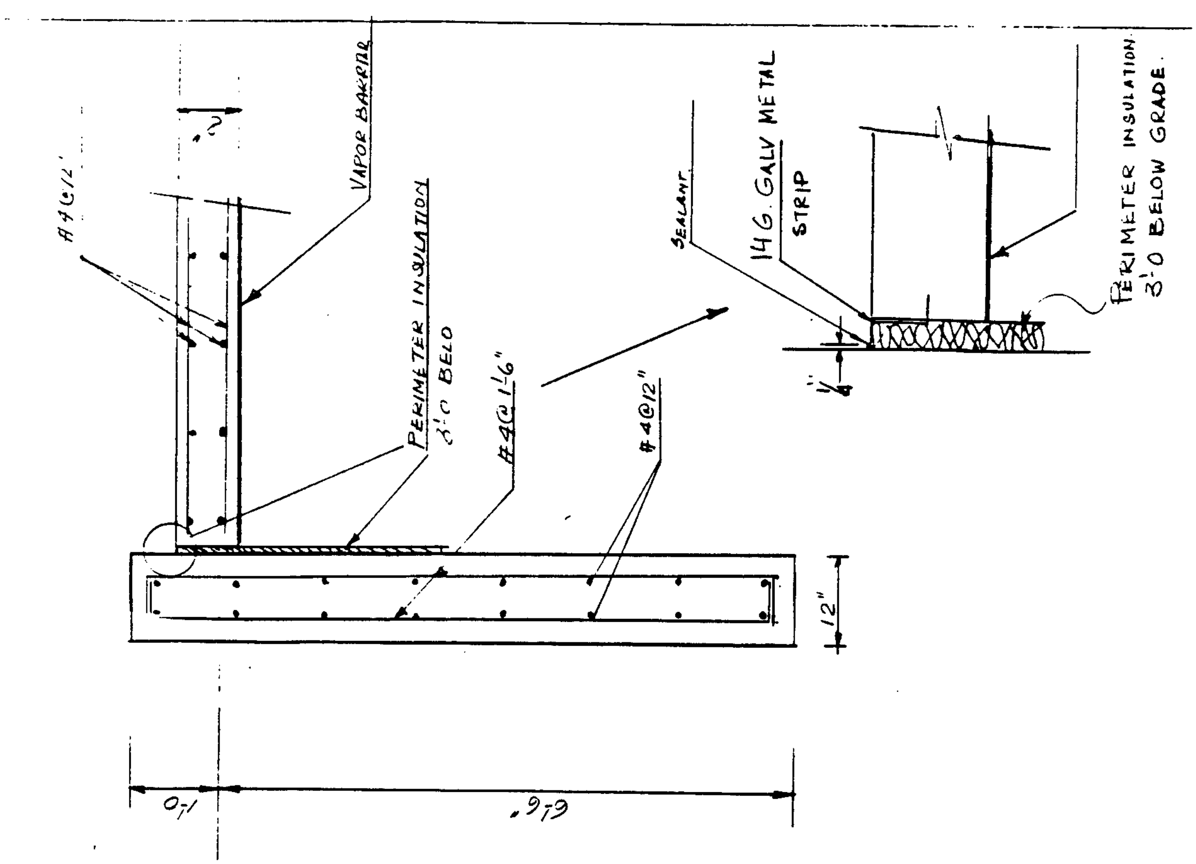
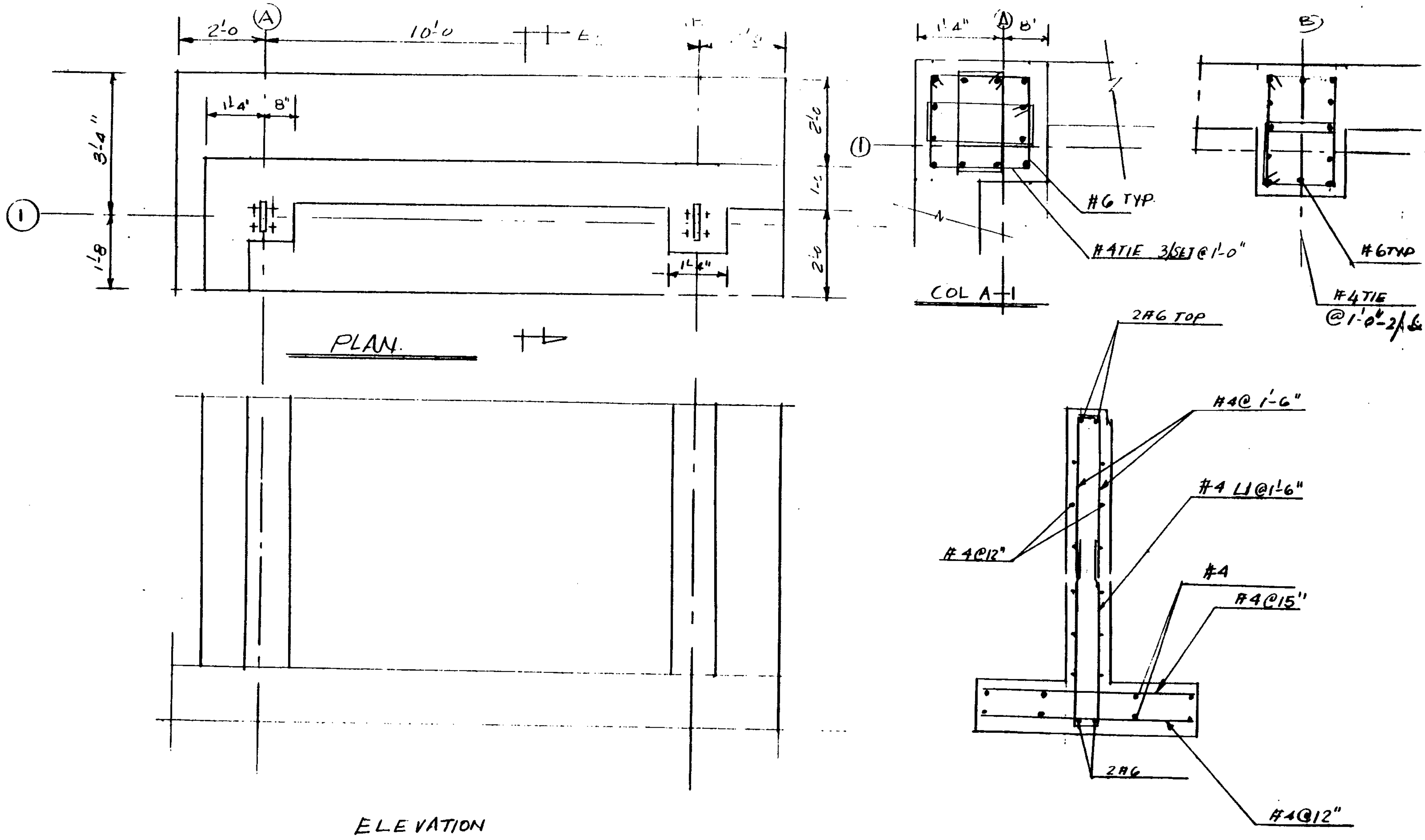

#4@12"
2"
VAPOR BARRIER
PERIMETER INSULATION
3'-0 BELO
#4@1'-6"
#4@12"
12"
1'-0
6'-6"
SEALANT
14G. GALV METAL
STRIP
1/4"
PERIMETER INSULATION
3'-0 BELOW GRADE.


2'-0
10'-0
3'-4"
1'-8
1'-4'
8"
2'-0
1'-4"
PLAN
ELEVATION
1'-4"
8'
#6 TYP
#4TIE 3/SET @1'-0"
COL A-1
#6TYP
#4TIE
2#6 TOP
#4@1'-6"
#4 LI@1'-6"
#4@12"
#4
#4@15"
2#6
#4@12"